

PERCEPTION

VOLUME 35

SUPPLEMENT



ECVP 2006

29th European Conference on Visual Perception
St Petersburg 20–25 August 2006

Abstracts

Twenty-ninth European Conference on Visual Perception

St Petersburg, Russia

20–25 August 2006

Abstracts

SUNDAY

The *Perception* lecture (J D Mollon) 1

MONDAY

ORAL PRESENTATIONS

The perception of time 1

Dorsal and ventral streams in the visual system 3

Optical properties of the eye 5

Perceptual learning in attention and visual search 7

Binocular vision and stereopsis 9

The representation of space and dynamic update during eye movements 10

Neuronal processing of visual image signalling: from neuronal circuits to human perception 12

Noise and uncertainty 14

Theory and models 16

Attention, eye movements, action 19

Colour processing and colour constancy 21

POSTER SESSION

Binocular and stereo vision 23

1-D, 2-D, 3-D shape, scene, space 33

Perceptual learning 40

Vision deceived 42

Perception in context 44

Image processing, applications, models 48

TUESDAY

ORAL PRESENTATIONS

The gate of perception: information transformation in the LGN 58

Matched filtering in human vision 59

Time and timing in biological systems 61

Behaviour in natural environment 63

Spatiotemporal vision 66

The nature of the visual code in sensory comparisons over time and space 67

Motion from the bottom up: from detection to cognition 69

Psychophysical, electrophysiological, and brain imaging approaches to segmentation and grouping in space and time 70

Cognitive influence on visual tasks 74

POSTER SESSION

Segmentation and grouping 76

Reading 80

Eye movements, saccades 82

Noise, uncertainty, templates 88

Development and ageing 90

Combining features into figures, objects, scenes 98

Timing and temporal dynamics 100

Neural coding 102

Cognition, decision 104

Spatiotemporal vision 108

WEDNESDAY

ORAL PRESENTATIONS

Associative learning in perception (Pavlov and perception) 113

The cone/rod dichotomy: molecules and cell morphology 116

Social perception and biological motion: brain imaging perspectives 119

Neurophysiology of primary visual cortex and perception 121

Brain area interaction 123

Varieties of multiple-object tracking 125

Temporal dynamics 127

POSTER SESSION

Visual function: testing and treatment 129

Vision through the eyes of animals 138

Optic flow 144

Heading and orienting in visual space 146

Vision and action 147

Attention, visual search, change detection, change blindness 154

THURSDAY

ORAL PRESENTATIONS

Evolution of vision 165

From perceptual to economic decisions 169

Binocular vision, stereopsis 170

Crowding (including lateral masking, illusory conjunctions, surround suppression, and attention) 172

SYMPOSIUM

Colour space: its structure and biological basis—In honour of Prof. E N Yustova 175

THURSDAY (continuation)

ORAL PRESENTATIONS

Hand, arm, and body coordination in visual space	177
Lightness, brightness, illumination	180
Seeing 3-D: surface, shape, space, motion	182

POSTER SESSION

Colour space: its structure and biological basis	185
Crowding	187
Vision and gravity	188
Colour: optics and retina	189
Colour: chromatic mechanisms	191
Colour: clinical	196
Fine eyes and arts	198
Audiovisual interaction	201
Face perception	206
Lightness, brightness, transparency	213
Motion perception, biological motion	215

FRIDAY

ORAL PRESENTATIONS

Vision and gravity	222
Art—perception and imagination	224
Shadow/illumination	227
Saccades, eye movements	228
Testing of visual function	230
Functional mapping	233
Attentive visuomotor processes	235
Motion perception	237
Face perception	240

Author index	243
--------------	-----

Organising Committee

Alexeenko S V	Pavlov Institute of Physiology, St Petersburg, Russia
Boiko E V	Medical Military Academy, St Petersburg, Russia
Chihman V N	Pavlov Institute of Physiology, St Petersburg, Russia
Danilova M V	Pavlov Institute of Physiology, St Petersburg, Russia
Donskoy D K	Russian Academy of Sciences, St Petersburg, Russia
Harauzov A K	Pavlov Institute of Physiology, St Petersburg, Russia
Koskin S A	Medical Military Academy, St Petersburg, Russia
Makarov F N	Pavlov Institute of Physiology, St Petersburg, Russia
Mollon J D	Cambridge University, UK
Podvigin N F	Pavlov Institute of Physiology, St Petersburg, Russia
Shelepin Y E	Pavlov Institute of Physiology, St Petersburg, Russia (Coordinator)
Shevelev I A	Institute of Higher Nervous Activity, Moscow, Russia
Toporova S N	Pavlov Institute of Physiology, St Petersburg, Russia
Troscianko T	Bristol University, UK
Vahrameeva O A	Pavlov Institute of Physiology, St Petersburg, Russia
Watson A B	NASA, Moffett Field, California, USA

Scientific Committee

Tiziano A Agostini	Hélène Gauchou	Susana Martinez-Conde	Hannah Smithson
David Alais	Emmanuelle Gavault	John Mollon	Sasha Sokolov
Magali Albert	Sergei Gepshtein	Marko Nardini	Alessandro Soranzo
Ben Backus	Lewis D Griffin	Harold T Nefs	Bill Stine
Ben Balas	Wolf Harmening	Vizireanu Dragos Nicolae	Igor Timofeev
Cordula Becker	Monika Harvey	Hans P Op de Beeck	Nelson Torro Alves
Patricia Bestelmeyer	Priscilla Heard	Daniel Osorio	Srimant P Tripathy
Valérie Bonnardel	Hauke R Heekeren	Lucas Paletta	Chia-huei Tseng
Oliver Braddick	Markus Hofbauer	Marina Pavlova	Tzvetomir Tzvetanov
Eli Brenner	Joerg Wolfgang Huber	Pauline M Pearson	Frans Verstraten
David P Carey	Li Jingling	Cesar V Ramirez	Tony Vladusich
Guido Marco Cicchini	Joni Karanka	Anina Rich	Quoc Vuong
Yann Coello	Almut Kelber	Tricia Riddell	Andrew Watson
Marina V Danilova	Ansgar Koene	Arash Sahraie	Mark Alexander Williams
Lisa M DeBruine	Arno Konig	Véronique Salvano-Pardieu	Qasim Zaidi
Joao Paulo de Sousa	Vladislav Kozyrev	Ayşe Pinar Saygin	Johannes Zanker
Claudio de'Sperati	Armin Lak	Andrew Schofield	Daniele Zavagno
Fulvio Domini	Keith Langley	Nick Scott-Samuel	Suncica Zdravković
Ali Ezzati	Joan Lopez-Moliner	Yuri Evgenii Shelepin	
Fiser Galmonte	Marianne Maertens	Ruxandra Sireteanu	

Supporting organisations

St Petersburg Government: Committee of External Relations	European Office of Aerospace Research and Development of the US Air Force
St Petersburg Government: Committee for Science and Education	Russian Foundation for Basic Research
Russian Medical Military Academy	IBRO
Russian Academy of Sciences	Pulkovo Airlines
	HFSP
	Pion Ltd

Acknowledgements

ECVP2006 logo by Sergey Pronin

ECVP2006 website and user interface by Cezar Ramirez and Eugeniy Shelepin

ECVP

The European Conference on Visual Perception is an annual event. Previous conferences took place in:

1978 Marburg (D)	1985 Peñíscola (E)	1992 Pisa (I)	1999 Trieste (I)
1979 Noordwijkerhout (NL)	1986 Bad Nauheim (D)	1993 Edinburgh (GB)	2000 Groningen (NL)
1980 Brighton (GB)	1987 Varna (BG)	1994 Eindhoven (NL)	2001 Kuşadası (TR)
1981 Gouvieux (F)	1988 Bristol (GB)	1995 Tübingen (D)	2002 Glasgow (GB)
1982 Leuven (B)	1989 Zichron Yaakov (IL)	1996 Strasbourg (F)	2003 Paris (F)
1983 Lucca (I)	1990 Paris (F)	1997 Helsinki (FI)	2004 Budapest (H)
1984 Cambridge (GB)	1991 Vilnius (LT)	1998 Oxford (GB)	2005 A Coruña (E)

ECVP '06 Abstracts

SUNDAY

THE PERCEPTION LECTURE

◆ Balls, bullets, and shot

J D Mollon (Department of Experimental Psychology, University of Cambridge, Downing Street, Cambridge CB2 3EB, UK; e-mail: jm123@cam.ac.uk)

Exactly 250 years ago, in the Academy of Sciences in St Petersburg, Mikhail Vasil'evich Lomonosov proposed that the retina contained three different types of particles, each of which was thrown into motion by light of a different colour. We now know that Lomonosov's particles correspond to three different opsins, segregated in different classes of cone. These opsins are polymorphic in our population: 6% of men are anomalous trichromats, making colour matches that are quite distinct from those of the normal phenotype. Since each class of cone individually obeys the principle of univariance, colour vision depends on post-receptoral channels that extract the ratios of photon catches in different classes of cone. There are at least three such channels at the early stages of the visual system. They did not all evolve at the same time, and they remain morphologically and immunologically different from one another. A current problem in colour theory is that these chromatically opponent channels do not map on to the axes of our phenomenological colour space. There are five colours that are phenomenologically unmixed: red, green, yellow, blue, and white. Should we look outside ourselves for the basis of these unique hues? Or even in the heavens?

MONDAY

ORAL PRESENTATIONS

THE PERCEPTION OF TIME

◆ Neuroanatomical localisation of preparatory and stimulus-evoked activity during visual timing

J T Coull, F Vidal, F Macar (Laboratoire de Neurobiologie de la Cognition [LNC], Université de Provence, Pole 3C, 3 place Victor-Hugo, F 13331 Marseille Cedex 3, France; e-mail: jcoull@up.univ-mrs.fr)

Attention modulates our subjective perception of time: the less we attend to an event's duration, the shorter it seems to last. Using fMRI we identified brain areas whose activity varied as a function of attentional allocation to stimulus duration versus colour. An attentional cue directed attention in a parametric manner towards one or both features of an upcoming stimulus. First, brain activity was measured at stimulus onset. Monotonically increasing attentional selectivity to colour increased activity in area V4. Conversely, increasing attentional selectivity to stimulus duration increased activity primarily in preSMA and right ventral premotor cortex, identifying these regions as core components of the perceptual timing network. Second, brain activity was measured at cue onset. As subjects prepared to attend more to stimulus colour, activity increased in an area of ventral extrastriate cortex just posterior to V4. Conversely, as subjects prepared to attend more to stimulus duration, activity increased in SMA proper. These areas may represent functionally specialised targets of top-down feedback that biases adjoining feature-specific processing areas in preparation for impending feature selection. Our results also demonstrate the flexibility of the attentional mechanisms involved, since both stimulus-evoked responses and preparatory baseline activity varied parametrically as a function of attentional selectivity.

[Supported by a Marie Curie Fellowship of the European Community programme Human Potential, under contract number HPMF-CT-2002-01525.]

◆ Distorting the apparent duration of visual events

A Johnston, J Watanabe¶, A Bruno, D H Arnold\$, S Nishida# (Department of Psychology, University College London, Gower Street, London WC1E 6BT, UK; ¶ Graduate School of Information Science and Technology, University of Tokyo, 7-3-1, Hongo, Tokyo 113-8656, Japan; \$ Department of Psychology, University of Queensland, Brisbane, QLD 4072, Australia; # NTT Communication Science Laboratories, NTT Corporation, 3-1 Morinosato Wakamiya, Atsugi-shi, Kanawaga 243-0198, Japan; e-mail: a.johnston@ucl.ac.uk)

The perceived duration of a 500 ms sinusoidally modulated (10 Hz) Gaussian luminance blob is reduced by around 20% after adaptation to a higher (20 Hz) temporal frequency but is hardly

Monday

affected by adaptation to a lower (5 Hz) temporal frequency (Johnston et al, 2006 *Current Biology* **16** 472–479). This apparent temporal compression is not the result of differential delays of the perceived time of onset or offset of the pattern, which were independently measured by comparing the time of onset and offset against an auditory noise burst. Therefore adaptation does not act to modify the sensory signal. The temporal effect is not mediated by concomitant changes in apparent temporal frequency as adaptation to higher and lower temporal frequencies results in an apparent repulsion of test frequency whereas only adaptation to high temporal frequency reduces apparent duration. Adaptation to a very high temporal frequency (50 Hz), at or above the critical flicker fusion threshold, also leads to a reduction in the perceived duration for a 10 Hz test stimulus, implicating the magnocellular system in time compression.

[Supported by HFSP & NTT.]

◆ **Judging temporal duration during normal vision and during saccadic eye movements**

D C Burr, M C Morrone¶ (Istituto di Neuroscienze del CNR, via Moruzzi 1, I 56000, Pisa, Italy; ¶ Università Vita-Salute San Raffaele, via Olgettina 58, I 20132, Milano, Italy; e-mail: dave@in.cnr.it)

Accurate timing over the subsecond scale is essential for a range of human perceptual and motor activities, but the mechanisms for encoding this time scale remain poorly understood. Recent work suggests that timing does not involve a centralised clock, but patterning within a local distributed neural network. We present and discuss recent experiments and models of duration estimation in conditions of adaptation and masking, and during saccades. All these factors can dramatically influence time perception. Time is compressed and even inverted during saccadic eye movements. Masking and adaptation also affect apparent duration in a spatially localised manner (Johnston et al, 2006 *Current Biology* **16** 472–479). More recent experiments show that if gaze is shifted between adaptation and test periods, the effects of adaptation on temporal duration are both retinotopic and also spatiotopic. This result sits nicely with Janssen and Shadlens' (2005, *Nature Neuroscience* **8** 234–241) evidence that neurons in parietal cortex, whose receptive fields shift around the time of saccades, are instrumental in coding subsecond intervals.

◆ **How the brain dynamically recalibrates timing judgments**

D M Eagleman (Department of Neurobiology and Anatomy, University of Texas Houston, 6431 Fannin Street, Houston, TX 77030, USA; e-mail: deagleman@uth.tmc.edu)

While walking through the forest you hear a twig crack. Did the sound occur when your foot fell, or just before? If it happened just before, the sound may alert you to a nearby predator. If the sound was coincident with your step, it was consistent with sensory feedback expected during walking. Survival and learning depend on correctly judging the order of motor action and sensory input. However, the ability to correctly judge temporal order is confounded by the fact that delays in sensory pathways can change (owing to lighting conditions, limb growth, etc). Thus, nervous systems constantly readjust motor-sensory timing estimates to reliably report when events occurred. A series of new experiments is presented that reveal neural mechanisms by which animals use self-generated actions to calibrate the timing between signals from different modalities. By manipulating the timing of sensory events, novel temporal illusions are demonstrated in which perceived order of action and event are reversed. fMRI BOLD signals suggest the existence of multiple timing representations that have different time scales of plasticity. These results are leveraged into new experiments on how the brain calibrates its timing of predictive models, and also whether subjective time can move in slow motion.

◆ **Time and attention in macaque area LIP**

P Janssen, E Premereur (Laboratorium voor Neuro-en Psychofysiologie, University of Leuven Medical School, Herestraat 49, bus 1021, B 3000 Leuven, Belgium; e-mail: peter.janssen@med.kuleuven.be)

We previously showed that neural activity in macaque area LIP represents the subjective hazard rate of elapsed time (Janssen and Shadlen, 2005 *Nature Neuroscience* **8** 234–241). Here, we studied the responses of LIP neurons when three possible go-cues and one target were presented in the visual field. The monkey's task was to make a saccade to the green target after one of the (blue) go-cues dimmed (the go-signal). In one block of trials, the dimming of the go-cue varied randomly among the three go-cue locations (random condition, divided attention), while in a second block of trials the dimming of the go-cue always occurred at the same position (fixed condition, selective attention). The timing of the go-signal was a random number drawn from a bimodal distribution. LIP activity mimicked the hazard rate: the spike rate showed a bimodal profile during target-in-RF trials, but remained relatively constant when one of the possible go-cues was in the receptive field (RF). Switching from the random condition to the fixed condition

resulted in elevated neural activity both for target-in-RF trials and go-cue-in-RF trials, without changing the shape of the activity profile. Thus, LIP neurons exhibit both effects of spatial attention and anticipation of the timing of the go-signal.

[Supported by FWO, GSKE, and HFSP.]

DORSAL AND VENTRAL STREAMS IN THE VISUAL SYSTEM

◆ Evoked potentials specific to global visual coherence in adults and infants

O J Braddick§, D B Birtles¶, J Warshafsky, F Akthar¶, J Wattam-Bell¶, J Atkinson¶
(§ Department of Experimental Psychology, University of Oxford, South Parks Road, Oxford OX1 3UD, UK; ¶ Department of Psychology, Visual Development Unit, University College London, Gower Street, London WC1E 6BT, UK; e-mail: oliver.braddick@psy.ox.ac.uk)

Coherence sensitivity for patterns of moving dots or oriented elements is increasingly used to assess extrastriate global function in dorsal and ventral streams. We have developed a visual evoked potential (VEP) test of global processing in infants and adults. Coherent and incoherent arrays (contour or motion) alternate at 0.5–4 Hz. Local changes at each transition may elicit a second harmonic VEP signal (F2), but a first harmonic (F1) must reflect differential global responses to coherence onset and offset. Supporting this, F1 in adults increases linearly with coherence, while F2 shows little variation. Motion coherence yields larger signals than form, but extrapolating amplitude vs coherence plots suggests similar thresholds for the two systems, consistent with psychophysical results. We have identified global form and motion VEP responses with infants aged 9–23 weeks. VEP signals remain constant through this age range for motion, but increase monotonically for form. Adult psychophysical coherence thresholds show only small effects of optical blur, suggesting that immature acuity is not a limiting factor in the development of these responses. These results suggest global integration as a feature of the motion pathway very soon after it emerges in cortical processing, while integrative processes in form processing develop more gradually.

[Supported by MRC programme grant G7908507.]

◆ ‘Dorsal vulnerability’ and patterns of visuo-cognitive deficit following very premature birth

J Atkinson, O J Braddick¶, M Nardini¶, S E Anker, F M Cowan§, A D Edwards§, M A Rutherford## (Visual Development Unit, Department of Psychology, University College London, Gower Street, London WC1E 6BT, UK; ¶ Department of Experimental Psychology, University of Oxford, South Parks Road, Oxford OX1 3UD, UK; § Department of Paediatrics [## Imaging Sciences Department], Imperial College, Hammersmith Hospital, London, UK; e-mail: j.atkinson@ucl.ac.uk)

Very prematurely born infants are at risk of long-term neurological and cognitive deficits. Visual cortical functions, which develop rapidly in the months after term, potentially provide a sensitive indicator of disruption to normal brain development and a prognosis of future development [Atkinson, 2000 *The Developing Visual Brain* (Oxford: Oxford University Press)]. We have studied infants born before 31 weeks gestation with two early cortical indicators, the orientation reversal VEP, and fixation shifts under competition. Deficits in both functions correlate with severity of white-matter damage seen on term MRI and with neurodevelopmental measures at 2 years. Follow up of these infants to the age of 6 years ($n = 78$) shows that even those with little or no white-matter damage perform below norms of spatial, perceptual, and attentional function, including motion coherence sensitivity, while form coherence sensitivity and language functions are normal. Relationships of these measures to the infant visual cortical indicators are discussed. Principal components analysis on all these follow-up measures shows one ‘frontal’ and another broadly parietal component. This analysis, and the relation between form and motion coherence sensitivity, extend the phenomenon of ‘dorsal stream vulnerability’ previously reported in a wide range of developmental disorders (Braddick et al, 2003 *Neuropsychologia* **41** 1769–1784).

[Supported by MRC programme grant G7908507.]

◆ Young children’s errors combining visual information for recognition and action

M Nardini, O J Braddick, J Atkinson¶ (Department of Experimental Psychology, University of Oxford, South Parks Road, Oxford OX1 3UD, UK; ¶ Department of Psychology, University College London, Gower Street, London WC1E 6BT, UK; e-mail: marko.nardini@psy.ox.ac.uk)

It has been debated why young children, disoriented in small enclosures, use enclosure shape but not wall colours to locate hidden toys (Hermer and Spelke, 1996 *Cognition* **61** 195; Nardini, 2006, PhD thesis, University College London). We ask whether this disregard of colour might not be specific to disorientation but exemplifies a more pervasive limitation on the interaction of dorsal- and ventral-stream information in early visual cognition. Infants, aged 18–24 months saw toys hidden in boxes distinguished by different colours (red, blue) and retrieval actions (pull, push).

Monday

Children had to discriminate between boxes to find the toy, based either on action alone, colour alone, or on the conjunction of the two. If action and colour information were combined independently, the rates of different kinds of conjunction errors would be predictable from the baseline rates of action and colour errors. However, our results showed that when action and colour had to be combined, colour information was lost significantly more often than predicted by these individual rates. Thus, children's disregard of colour is not limited to tasks involving disorientation. We argue that it may reflect failures in early development to combine ventral-stream information for recognition with dorsal-stream information used in action planning.

[Supported by Medical Research Council grant G7908507 and Economic and Social Research Council grant RES-000-23-1474.]

◆ **Anisotropic cortical responses for radial expansion/contraction in infants and adults**

N Shirai, D B Birtles[¶], J Wattam-Bell[§], M K Yamaguchi, S Kanazawa[#], J Atkinson[§], O J Braddick[‡] (Department of Psychology, Chuo University, 742-1 Higashinakano, Hachiohji-shi, Tokyo, 192-0393, Japan; [¶] Department of Psychology [[§] Visual Development Unit], University College London, Gower Street, London, WC1E 6BT; [#] Department of Psychology, Shukutoku University, Daiganji 200, Chiba 260-8701, Japan; [‡] Department of Experimental Psychology, University of Oxford, South Parks Road, Oxford OX1 3UD, UK; e-mail: o2341006@crow.grad.tamacc.chuo-u.ac.jp)

Radial expansion/contraction can be crucial cues of motion-in-depth perception such as objects approaching/receding or observers' own forward/backward motion. Here we report the anisotropic cortical responses (steady-state VEPs) to radial expansion/contraction in human infants and adults. A total of forty-four infants (twenty-two 3.5 months old and twenty-two 4.5 months old) and nine adults participated in the present study. The participants were exposed to stimuli composed of 2000 moving dots which cyclically alternated their motion directions between radial expansion (or contraction) and random directional motion. The speed of each dot was maintained at 6.8 deg s^{-1} . The pattern alternation occurred every 240 ms. Hence the frequency of pattern alternation in each stimulus was 2.085 Hz. We compared amplitudes of F1 (2.085 Hz) component in steady-state VEPs between expansion-random and contraction-random motion alternations (expansion condition and contraction condition, respectively). We found out that mean F1 amplitudes in the contraction condition were significantly larger than those in the expansion condition for the older infants and adults. These results suggest that the human cortical motion mechanisms have anisotropic sensitivities for radial expansion/contraction and the anisotropy may develop between 3.5 and 4.5 months of age.

[Supported by Medical Research Council (UK) programme grant G7908507 to JA, OJB, JW-B, and grant-in-aid for scientific research from the Japan Society for the Promotion of Science to NS (17-741).]

◆ **Infants see the 'Rotating Snake' illusion**

S Kanazawa, A Kitaoka[¶], M K Yamaguchi[§] (Department of Psychology, Shukutoku University, Chiba 260-8701, Japan; [¶] Department of Psychology, Ritsumeikan University, 56-1 Tojiin Kitamachi, Kita-ku, Kyoto 603-8577, Japan; [§] Department of Psychology, Chuo University, 742-1 Higashinakano, Hachiohji, Tokyo 192-0393, Japan; e-mail: kanazawa@soc.shukutoku.ac.jp)

A static figure called 'rotating snake' is a kind of 'Fraser-Wilcox illusion' (Fraser and Wilcox, 1979 *Nature* **281** 565–566) which produces strong illusory motion by the static arrangement of regions in different colours (<http://www.ritsumeik.ac.jp/~akitaoka/index-j.html>). This stimulus was invented by Kitaoka and recently investigated psychophysically (Backus and Oruc, 2005 *Journal of Vision* **5** 1055–1069) and neurophysiologically (Conway et al, 2005 *Journal of Neuroscience* **25** 5651–5656). Here, we used this 'rotating snake' as a stimulus and investigated the illusory perception in infants. Forty-one infants aged 6–8 months participated in this study. We prepared the original 'rotating snake' and controlled stimulus which was very similar in appearance to the original one but did not produce illusory motion. We presented these original and control stimuli side by side in the monitor and measured the infants' looking time to the original 'rotating snake'. In each trial the stimuli were presented for 15 s and four trials were conducted for each infant. Results of the ratio of looking time showed that infants looked at the 'rotating snake' significantly longer (58.97%, $t_{22} = 4.21$, $p < 0.001$). These results suggest that infants aged 6–8 months perceive the illusory motion produced by the specific arrangement of four-colour regions.

◆ Interaction between global form and motion processing

J Wattam-Bell, O J Braddick¶, J Atkinson (Visual Development Unit, Department of Psychology, University College London, Gower Street, London WC1E 6BT, UK;

¶Department of Experimental Psychology, University of Oxford, South Parks Road, Oxford OX1 3UD, UK; e-mail: j.wattam-bell@ucl.ac.uk)

Global form and global motion are thought to be processed separately by the ventral and dorsal visual streams respectively. Form and motion coherence thresholds are increasingly used as independent measures of normal and abnormal function and development of the two streams. But how independent are they? To assess this, we have examined the effect of motion masks on form coherence thresholds, and vice versa. The form stimulus consisted of dots arranged in short concentric arcs to produce a static global circular organisation. The motion stimulus contained dots moving along similar arcs, resulting in global rotation. Coherence was varied by changing the proportion of arcs that were concentrically arranged, with the rest being randomly oriented, and coherence thresholds for detecting the concentric organisation were measured in a 2IFC task. Form and motion thresholds were measured with no mask, and with superimposed masks of coherence between 0% and 32%. Across all conditions, coherence thresholds lay between 6% and 9% and were unaffected by the presence or coherence of the masks in the other domain. These results suggest little or no interaction between form and motion at either local or global levels for these stimuli; they provide effective measures of two independent systems.

[Supported by MRC programme grant G7908507.]

OPTICAL PROPERTIES OF THE EYE

◆ Restoration of accommodation in aphasic eye

L I Balashevich (Fedorov Center of Eye Microsurgery, St Petersburg Branch, Yaroslava Gashka 21, 192283 St Petersburg, Russia; e-mail: lib@mntk.spb.ru)

The purpose of this study was to investigate the possibility of restoration of near vision without eye glasses in human eyes after the removal of cataract-affected lens. The study was conducted on sixty-three patients aged 34–73 years (100 eyes) after a cataract-removal surgery. All patients were subjected to ultrasonic phacoemulsification and were implanted with a new diffractive apodised bifocal intraocular lens AcrysofRestor SA60D3 contained in a capsular bag. After the surgery and lens implantation all patients had distant visual acuity of 20/20 or better, and near visual acuity (distance = 30 cm) of 20/25 or better without any correction. The lenses did not significantly reduce contrast sensitivity and did not increase visual disturbances in mesopic conditions. More than 95% of patients were satisfied with the result of the operation. No complications were recorded during and after operation. The new method of phacoemulsification with implantation of a diffractive bifocal lens opens a new era in cataract surgery.

◆ Classification and physiological principles of accommodation mechanisms in the human eye

I N Koshits, O Svetlova¶, K Kotliar§, B Smolnikov#, F N Makarov‡ (Petercom/MS Consulting Group, St Petersburg, Russia; ¶Department of Ophthalmology, St Petersburg Medical Academy of Postgraduate Education, St Petersburg, Russia; §Department of Ophthalmology, Munich University of Technology, Ismaninger Strasse 22, D 81675 Munich, Germany; #Department of Mechanics and Control of Processes, St Petersburg Polytechnic University, St Petersburg, Russia; ‡Laboratory of Neuromorphology, Pavlov Institute of Physiology, Russian Academy of Sciences, nab. Makarova 6, 199034 St Petersburg, Russia; e-mail: petercom@sp.ru)

According to Helmholtz, lens accommodation represents the only accommodation mechanism. Generally, executive mechanisms of the accommodation are divided by us into intraocular and extraocular ones. Corneal and scleral mechanisms represent extraocular mechanisms of the accommodation. These manifest themselves in changing of the anterior–posterior axis of the eye when squeezing the sclera, narrowing lids in order to increase the depth of focus, and changing of the corneal astigmatism by lids and the ciliary muscle. Intraocular mechanisms of the accommodation were subdivided into several extracapsular and intracapsular ones (according to Gullstrand). The extracapsular mechanisms are represented by: narrowing of the pupil; uniform rounding of the surfaces of the lens capsule (described by Helmholtz); changing of the lenticular astigmatism (nonuniform lens accommodation in different meridians); displacement of the lens capsule along the optic axis of the eye; stationary adjustment of the retina; displacement of the retina; as well as by changing of the choroidal elasticity at different perfusion rates. Presumably, the first mechanisms switched on in the eye are narrowing lids and narrowing the pupil as well as changing of the corneal astigmatism.

Monday

◆ Investigation of meridional accommodation in children with anomalies of refraction

V I Serdyuchenko, I A Viazovsky, I N Kuzhda[¶] (Institute of Eye Diseases and Tissue Therapy, Frantsuzsky blvd 49/51, 65061 Odessa, Ukraine; [¶]City Clinical Hospital, 76000 Ivano-Frankovsk, Ukraine; e-mail: iryna54@mail.ru)

A new method is proposed for the measurement of absolute accommodation volume in different meridians of the eye. Eight children with spherical hyperopia and one hundred and ninety children with different kinds of astigmatism were tested (aged 7–15 years). Measurement of nearest distance of clear vision (NDCV) was carried out in 6 meridians of each eye: 0°, 30°, 60°, 90°, 120°, and 150°. For each child with a spherical refraction the obtained values of NDCV were either identical in different meridians, or differed by 0.25–0.75 D. In all tested patients with astigmatism the NDCV values varied in different meridians; the range of variation was 0.9–5.5 D. Minimal and maximal values of NDCV were measured in the main meridians of the astigmatic eyes. Only in 4%–9% cases the accommodation was found to be regular and did not influence the degree of astigmatism. In 21%–30% of eyes, irregular accommodation completely compensated the existing astigmatism; in 45%–48% of eyes the compensation was only partial, and in 13%–45% of eyes the astigmatism was even strengthened. The dependence of uncorrected visual acuity on the peculiarities of accommodation was investigated.

◆ Physiological and clinical aspects of the dry eye syndrome

E E Somov (Fedorov Center of Eye Microsurgery, St Petersburg Branch, Yaroslava Gasheka 21, 192283 St Petersburg, Russia; e-mail: alenaru@mail.ru)

The dry eye syndrome (SDY) is one of the most common eye diseases. The loss of the cyclic mechanism which is responsible for precorneal renovation of the tear film is the reason for inevitable local sclerosis. In our clinic we distinguish three aetiological types of SDY: syndromic, symptomatic (this is accompanied by another eye disease and hence use of some drugs), and artificial (the result of harmful exogenic influence). Clinical appearances of SDY, which can vary, depend on the severity of the disease. In all cases corneal epithelium is involved, from micro-erosion (which can be determined only by tincturing) to striate keratitis (which is clearly seen with bare eyes). In diagnostics of SDY, besides patients' complaints and anamnesis, two well-known tests are important: (i) establishing the period of the breakup of the tear film (proposed in 1969 by N S Norn) and (ii) establishing the total tear flow (proposed in 1903 by O Schirmer). In the first stage of SDY conservative treatment should be applied in the form of eye drops and gels (for example, Oftagel, Systein). If such treatment does not bring stable relief, surgical methods, such as obturation of lachrymal plugs and lachrymal canaliculus are recommended.

◆ Ultrasound investigation of human accommodation

V V Strakhov (Department of Ophthalmology, Yaroslavl State Medical Academy, Revolyutsionnaya 5, 150000 Yaroslavl, Russia; e-mail: strakhov51@mail.ru)

Human accommodation was studied by means of an ultrasound biomicroscope (UBM) System 840 with introduction of a pilocarpine or an adrenaline solution, or without it on volunteers aged 20–25 years. It was found that half of the ligament apparatus of the lens has intermediate fastening in the ciliary body crown (CBC). After introduction of adrenaline solution the CBC and Zinn's intermediate attaching block was found to shift from the lens equator slightly forward to the iris root and scleral spur. This was accompanied by an increase of the curvature radius of the anterior lens surface up to 1.1 mm. After introduction of pilocarpine solution the CBC moved to the lens equator and slightly back in the frontal position. Decrease of Zinn's tension can be visualised by means of a UBM as a transformation of straight lines into arched lines, or even into wavelike lines in the zone between the CBC and the lens. Zinn's tones can actively change in the area between the CBC and the lens equator. It is suggested that a coronal mechanism of accommodation exists, and this mechanism can be regarded as an addition to the Helmholtz's theory.

◆ New measure of an estimation of a range of accommodation

V V Volkov, V I Matveev[¶], Y E Shelepin[§] (Department of Ophthalmology, Military Medical Academy, Lebedeva 6, 194044 St Petersburg, Russia; [¶]Consulting Ophthalmology Center, Mokhovaya 38, 194036 St Petersburg, Russia; [§]Pavlov Institute of Physiology, Russian Academy of Sciences, nab. Makarova 6, 199034 St Petersburg, Russia; e-mail: vv_volkov@hotmail.com)

Dependence of the nearest and most distant points of clear vision on the spatial position was determined in young (17–23 years-old) people with different refraction. Tests were carried out with sinusoidal gratings with spatial frequency ranging from 3.5 to 30.5 cycles cm⁻¹. Threshold distance in nearest and most distant points of clear vision was measured for each grating. We suggested a new measure for estimating accommodation volume in octaves (binary logarithm

of the ratio of the high frequency to the low frequency limit). This approach takes into account not only the distance to the object, but also its spatial frequency properties. Working accommodation range was defined for observers with different refraction (without correction and with different variants of optical correction). We showed that with a low degree of myopia, the working accommodation range in octaves is wide enough, being almost the same as for emmetropic observers, but it is localised at a nearer distance to the observer. In subjects within medium and high degrees of myopia the working accommodation range is smaller. We therefore propose a simple and effective new metrology for accommodation in octaves.

PERCEPTUAL LEARNING IN ATTENTION AND VISUAL SEARCH

◆ **Effective surround size in visual search: Dependence on eye viewing the target and distractors**

S Hochstein, E Shneor¶ (Institute of Life Sciences and Interdisciplinary Center for Neural Computation [¶ Department of Neurobiology], Hebrew University, IL 91904 Jerusalem, Israel; shaul@vms.huji.ac.il)

Detection of an element differing significantly from surrounding distractors is an easy task. Detection of an oddly oriented element depends only on local orientation gradients, and not on the number of distractors in the array. We asked if detection depends on the eye viewing the target and on the eye viewing nearest neighbours or even more distant elements. Using red–green glasses, subjects viewed a briefly presented 8×8 array of green and red lines oriented at 60° , followed by a masking stimulus. On half of the trials, one element was replaced by a target line oriented at 40° . In experiment 1, the 8 lines surrounding the target were controlled to have the same colour as the target, the opposite colour, or a mixture of the two colours. Other elements were randomly red or green. In experiment 2, surrounds were homogeneous: all distractors had the same colour, opposite colour, or half were of each colour. Odd-element detection depended on the eye viewing the target as well as that seeing surrounding elements—and on the extent of this uniform surround. We conclude that, as regards the viewing eye, detection does not depend only on local differences but is influenced also by more distant elements, perhaps even the entire array. [Supported by Israel Science Foundation “Center of Excellence” and US–Israel Binational Science Foundation (BSF).]

◆ **Exogenous attention effects on perceptual learning**

M Carrasco, A M Giordano (Department of Psychology and Center for Neural Science, New York University, 6 Washington Place, New York, NY 10003, USA; e-mail: marisa.carrasco@nyu.edu)

Covert attention improves discriminability and accelerates the rate of visual information processing. Here we examined perceptual learning using the speed–accuracy tradeoff (SAT) procedure, which enables conjoint measures of discriminability and speed of information processing. For ten consecutive days, naive observers performed an orientation-discrimination conjunction task in which a peripheral location cue preceded a target (low-frequency tilted) presented with distractors (high-frequency tilted and low-frequency vertical Gabors). The target appeared in one of eight iso-eccentric locations. A response tone prompted observers to respond after various lags (40–1500 ms). At the end of the ten sessions, observers performed a transfer task in which the identity of the target and one type of distractor was switched—observers searched for a high-frequency tilted target among low-frequency tilted and high-frequency vertical Gabors. In both the neutral and attentional conditions, both discriminability and processing speed (rate and intercept) improved over time. This improvement was due to perceptual learning. In the transfer task, performance was impaired when compared to the initial performance levels in the original task. These findings suggest that observers’ perceptual learning occurred because they processed the target preferentially while inhibiting the distractors, particularly in the attended condition.

◆ **The role of perceptual learning on modality-specific visual attentional effects**

M Chirimuuta, D C Burr¶, M C Morrone§ (Istituto di Neuroscienze CNR, via G Moruzzi 1, I 56010 Pisa, Italy; School of Philosophy and Bioethics, Monash University, Clayton, VIC 3800, Australia; ¶ Istituto di Neuroscienze del CNR, via G Moruzzi 1, I 56100 Pisa, Italy; § Università Vita-Salute San Raffaele, via Olgettina 58, I 20132 Milan, Italy; e-mail: mazviita.chirimuuta@arts.monash.edu.au)

Morrone et al (2002 *Current Biology* 12 1134–1137) reported that the detrimental effect on the contrast discrimination thresholds of peripheral gratings of performing a concomitant central task is modality-specific: performing a secondary luminance task has no effect on colour-contrast thresholds, and vice versa. Here we confirm this result with a novel distractor task involving learning of spatial position with a central stimulus comprising small, mostly randomly positioned, circles. We show that it is not specific to the cardinal colour axes: secondary tasks with red–green

Monday

stimuli impede performance on a blue–yellow task and vice versa. We further show that the attentional effect can be abolished with continued training over 2–4 training days (2–20 training sessions), and that the effect of learning is transferable to new target positions. The finding that learning does not transfer from luminance to colour tasks suggests that plasticity occurs in a sensory region and not in the high-level coordination of the double tasks. We discuss the possibility that V4 is a site of plasticity for both stimulus types, and that the separation is due to a luminance–colour separation within this cortical area.

[Supported by MIUR PRIN.]

◆ **Perceptual learning with masked stimuli**

M Fahle, T Eggert, S Wischhusen, K Spang (Human Neurobiology, University of Bremen, Argonnenstrasse 3, D 28211 Bremen, Germany; e-mail: mfahle@uni-bremen.de)

Perceptual learning seems to involve changes in early sensory cortices. To avoid interference with other tasks, these changes should be activated via top–down influences in a task-dependent way. We employed masks to decrease the possible influence of top–down feedback and to measure perceptual learning for variable stimulus onset asynchronies (SOAs). Observers had to indicate, in a binary task, whether a line presented on a CRT was bent to the right or to the left. Stimulus duration was 10 ms, and either before, simultaneously with, or after the stimulus, a 100 ms mask consisting of two flanking lines was presented. SOAs ranged between –100 and +400 ms. Each observer contributed more than 6000 responses. Initial thresholds were higher, by around a factor of 4, for short SOAs than for longer ones, indicating strong inhibition by the mask. Perceptual learning improved performance by up to a factor 2 even at very short intervals between stimulus and mask (SOAs) that should be too short for top–down influences to modify bottom–up processing. Hence, strong improvement is possible even at very short SOAs. Perceptual learning with masked stimuli is obviously based on learning to suppress the mask, rather than on improved top–down influences.

◆ **Training eye movements: Integrating top–down and bottom–up influences in visual search**

R C Dewhurst, D Crundall (School of Psychology, University of Nottingham, University Park, Nottingham NG7 2RD, UK; e-mail: lwxrcd@psychology.nottingham.ac.uk)

A central focus of vision research in recent decades has been to identify what visual search strategies people use in different contexts. Recent models of visual attention and eye movements have been primarily concerned with the bottom–up influences of stimuli, via salience maps, upon the decision to fixate a stimulus or to make a saccade to another stimulus. It is less clear however, how goal-directed strategies affect saccade generation via top–down control. This is the focus of the research to be presented. Using Findlay and Walker's (1999 *Behavioral and Brain Science* 22 661–721) model of saccadic eye movements as a basis, specific strategies to enhance the efficiency of participants' visual search have been developed. These 'training' principles are purposefully implemented to reduce response times to target stimuli via two routes in Findlay and Walker's model. It is argued that top–down control strategies can differentially affect the WHERE and WHEN pathways of Findlay and Walker's model, and that training can be directed to these pathways either independently or in concert, with different consequences. This research is particularly relevant to training the eye movements of novice practitioners of complex tasks (eg learner drivers), where there has been mixed success in the literature to date.

◆ **Discrimination training alters object representations in human extrastriate cortex**

H P Op de Beeck[¶], C I Baker, J J DiCarlo, N G Kanwisher (McGovern Institute for Brain Research, Massachusetts Institute of Technology, 77 Massachusetts Avenue, Cambridge, MA 02139, USA [[¶]] and Department of Psychology, University of Leuven, Tiensestraat 102, B 3000 Leuven, Belgium; e-mail: hans.opdebeeck@psy.kuleuven.be)

Visual object recognition relies critically on learning. However, little is known about effects of object learning in human visual cortex, in particular how the spatial distribution of training effects relates to the distribution of object and face selectivity across the cortex. We scanned human subjects with high-resolution fMRI while they viewed novel object classes, both before and after extensive training to discriminate between exemplars within one of these object classes. Training increased the strength of the response in visual cortex to trained objects compared with untrained objects. However, training did not simply induce a uniform increase in the response to trained objects: The magnitude of this training effect varied substantially across sub-regions of extrastriate cortex, with some showing a two-fold increase in response to trained objects and others (including the right fusiform face area) showing little effect of training. Furthermore, the spatial distribution of training effects could not be predicted from the spatial distribution of either pre-trained responses or face selectivity. Instead, training changed the spatial distribution

of activity across cortex. These findings support a dynamic view of the ventral visual pathway in which the cortical representation of an object category is continuously modulated by experience. [Supported by Human Frontiers Science Program.]

BINOCULAR VISION AND STEREOPSIS

◆ **Temporal dynamics of binocular rivalry imply an important role for noise**

J W Brascamp, R van Ee¶, A J Noest, A V van den Berg (Functional Neurobiology and Helmholtz Institute, Utrecht University, Padualaan 8, NL 3584 CH Utrecht, The Netherlands; ¶ Physics of Man and Helmholtz Institute, Utrecht University, Princetonplein 5, NL 3584 CC Utrecht, The Netherlands; e-mail: j.w.brascamp@bio.uu.nl)

When our eyes independently view dissimilar images, we perceive an ongoing alternation between the images: binocular rivalry. The alternation cycle of rivalry comprises periods of exclusive dominance and transition periods during which both images are partly visible. Two key driving forces are self-adaptation of, and cross-inhibition between, the neural representations of the two images. Models based on these factors correctly reproduce dominance durations, but their predictions on transitions are unknown. We studied the temporal dynamics of rivalry in relation to stimulus contrast, considering dominance durations, transition durations, and the occurrence of return transitions: occasions on which an eye loses and regains dominance without an intervening dominance period of the other eye. In simulations we investigated if existing models could reproduce our findings. We find that dominance durations and the incidence of return transitions depend similarly on contrast; transition durations show a different dependence. We also demonstrate that previous descriptions of contrast dependence of dominance durations are incomplete. Our data refute existing models, particularly the large transition durations and high frequency of return transitions. We argue that deterministic factors are insufficient to explain rivalry, and show that noise is a crucial driving force. Relevant models should cover this interplay between deterministic and stochastic forces.

◆ **Effects of hyperstereopsis on perceived slope and estimates of time to contact**

P Flanagan, G Stuart¶, P Gibbs¶ (School of Psychology, Deakin University, Geelong, VIC 3217, Australia; ¶ Air Operations Division, Defence Science and Technology Organisation, 506 Lorimer Street, Fishermans Bend, VIC 3144, Australia; e-mail: flanagan@deakin.edu.au)

Some night-vision systems have sensors mounted on the sides of the helmet with visual output projected onto a display in front of the operator's eyes. This arrangement produces a situation of hyper-stereopsis in which binocular cues available to the operator are exaggerated so that distances around fixation are magnified. We used computer-generated graphics and a z-screen, and passive polarised glasses to simulate hyper-stereopsis to measure its effects on (a) perceived slope and (b) estimates of time to contact (TTC) to see if hyper-stereoscopic cues influenced slope and TTC judgments, over and above those from monocular cues (eg texture gradient and optic flow). We found that slope was overestimated under conditions of hyper-stereopsis and TTC judgments were underestimated though we observed that the misestimations were less than would be expected given the four times greater interpupillary distance employed. These distortions in perceived slope and judged TTC support reports of visual distortions from pilots who use these devices in the field. [Supported by the Defence Science and Technology Organisation.]

◆ **The depth of suppression during monocular rivalry and binocular rivalry**

R P O'Shea, D Alais¶, A Parker§ (Department of Psychology, University of Otago, PO Box 56, Dunedin, New Zealand; ¶ Department of Physiology and Institute for Biomedical Research, School of Medical Science, University of Sydney, NSW 2006, Australia; § Department of Psychology, University of Sydney, NSW 2006, Australia; e-mail: r.oshea@otago.ac.nz)

Monocular rivalry, also known as pattern rivalry, occurs when two different, optically superimposed images are viewed: the images alternate irregularly in their clarity. It is similar to, but much weaker than, binocular rivalry, which occurs when two different images are presented to opposite eyes. In both phenomena, for a few moments one image dominates visual awareness while the other image is suppressed. To assess the depth of suppression we measured thresholds to detect a brief contrast increment to one image while it was suppressed and to the same image while it was dominant. Suppression thresholds during binocular rivalry were about 45% higher than dominance thresholds. Suppression thresholds during monocular rivalry were about 10% higher than dominance thresholds. Suppression depth in monocular rivalry is significant but much weaker than in binocular rivalry, consistent with the weak appearance of the monocular rivalry.

Monday

◆ **A model of perceived bar rotation, the Venetian-blind effect, in square-wave gratings as a function of contrast disparity**

W W Stine, R S Hetley (Department of Psychology, Conant Hall, University of New Hampshire, Durham, NH 03842, USA; e-mail: bill.stine@unh.edu)

When a square-wave grating with either luminance or contrast disparity is viewed, one often perceives a rotation of the individual bars (the Venetian-blind effect: Cibis and Haber, 1951 *Journal of the Optical Society of America* **41** 676–683; Filley and Stine, 1998 *Perception* **27** Supplement, 99). Stine et al (2004 *Perception* **33** Supplement, 39) developed a description of the effect where the p th root of a difference of p th powers of the luminance or contrast in the image in each eye predicts the degree of perceived rotation. We now offer a theoretically substantive and simple model of the Venetian-blind effect. Using Naka–Rushton equations that describe the response of V1 cells in *Macaca* cortex (Sclar et al, 1990 *Vision Research* **30** 1–10) and descriptions of perceived slant as a function of horizontal size ratio (Backus et al, 1999 *Vision Research* **39** 1143–1170), we present a model where the perceived horizontal size ratio is a linear function of the difference in response of cortical cells to the contrast of the image in each eye. The perceived horizontal size ratio, with perceived values for other relevant variables (eg vertical size ratio), then determines perceived rotation.

◆ **Bilateral symmetry in binocular vision**

C J Erkelens, R van Ee (Helmholtz Institute, Utrecht University, Princetonplein 5, NL 3584 CC Utrecht, The Netherlands; e-mail: c.j.erkelens@phys.uu.nl)

Human vision is highly sensitive to bilateral symmetry in 2-D images. It is not clear yet whether our visual sensitivity relates to image symmetry itself or that image symmetry is regarded as a special case of object symmetry. 2-D images are not appropriate stimuli to address this question. We used a bisection task during the viewing of stereograms to study bilateral symmetry in 3-D stimuli. Beneficial properties of using bisection are that human subjects can do it with great accuracy and that image and object symmetry make different predictions. The bisection stimulus consisted of three parallel lines of which two lines were located in one depth plane and the third one in another. Bisection judgments of horizontal lines showed that bisection was related to image symmetry independently of object symmetry. Bisection of vertical lines showed that bisection was related to image symmetry in either the left or the right eye. Which eye's image was symmetric appeared to be given by the orientation of the plane of symmetry of the bisection stimulus relative to the subject's head. The image was symmetric in the eye that was closest to the plane of stimulus symmetry.

◆ **The perceived depth of a dot cloud is the centroid of the disparity distribution**

D R T Keeble, J M Harris¶, I Pacey (Department of Optometry, University of Bradford, 2 Richmond Road, Bradford BD7 1DP, UK; ¶ School of Psychology, University of

St Andrews, St Andrews KY16 9JU, Scotland, UK; e-mail: D.R.T.Keeble@Bradford.ac.uk)

Spatial position and texture orientation appear to be encoded as the centroid (ie mean) of the distribution of the relevant variable. Although the perception of stereoscopic depth has been extensively investigated, little is known about how separate estimates of disparity are combined to produce overall perceived depth. We employed base-in prisms mounted on a trial frame and half-images presented on a computer screen, to produce stereoscopic images of dot clouds with skewed (ie asymmetrical) distributions of disparity. Three subjects judged in a 2AFC task whether the dot cloud was in front of or behind an adjacent flat plane of dots. Psychometric functions were generated and the point of subjective equality was calculated. For dot clouds of thickness up to about 6 min of arc disparity, the perceived depth was close to the centroid for all three subjects, regardless of skew. For thicker clouds (we tested thicknesses up to 25 min of arc), the perceived depth was slightly closer to the subject than the centroid, regardless of skew. The human visual system therefore integrates depth information veridically for thin surfaces. For thick surfaces, the dots closest to the observer have a higher weighting, possibly owing to their greater salience.

THE REPRESENTATION OF SPACE AND DYNAMIC UPDATE DURING EYE MOVEMENTS

◆ **A corollary discharge for perceptual stability**

R H Wurtz, M A Sommer¶ (Laboratory of Sensorimotor Research, National Eye Institute, NIH, Building 49, 2A50, Bethesda, MD 20892-4435, USA; ¶ Department of Neuroscience and Center for the Neural Basis of Cognition, University of Pittsburgh, 446 Crawford Hall, Pittsburgh, PA 15260, USA; e-mail: bob@lsr.nei.nih.gov)

Helmholtz argued that our percept of visual stability in spite of saccadic eye movements results from an input to visual processing by an 'effort of will'. This input, known as efference copy or corollary discharge, provides information about the impending eye movement and permits

compensation for the visual effect of the movement. We have recently identified a pathway in the monkey brain that could convey such a corollary discharge signal from the superior colliculus in the brain stem through the medial dorsal nucleus of the thalamus (MD) to the frontal eye fields of the cerebral cortex. We have now investigated whether this pathway might contribute to the perception of a stable visual world. We tested whether a possible mechanism of this stability—the shifting receptive fields in anticipation of an impending saccade discovered by Duhamel, Colby, and Goldberg—might be dependent upon the identified corollary discharge pathway. We found that inactivation of MD did alter this shift indicating that the shift does indeed depend upon the corollary discharge. The combined findings of the shifting receptive fields and their dependence on an identified corollary discharge give insight at a neuronal level of the brain mechanisms underlying the stability of visual perception.

◆ **Active vision and corollary discharge: When the brain is split, is space still unified?**

C L Colby (Department of Neuroscience, University of Pittsburgh, Pittsburgh, PA 15260, USA; e-mail: colby@cncb.cmu.edu)

How does the brain keep track of visual stimuli when the eyes move? In parietal, frontal, and extrastriate cortex, and in the superior colliculus, neurons remap stimulus representations in conjunction with eye movements. The circuitry that produces remapping in two split-brain monkeys was investigated. The hypothesis was that the forebrain commissures provide the primary route for remapping memory traces of salient stimuli across visual hemifields. A striking initial impairment was observed in the monkeys' ability to remap stimuli across hemifields in the double-step task. Surprisingly, however, the animals were ultimately capable to perform these sequences accurately. In subsequent physiological experiments, neurons in lateral intraparietal cortex (LIP) were found to be still activated by remapped visual signals, even when those signals originated in the opposite hemisphere. These behavioural and neurophysiological findings indicate that the transfer of visual information is not abolished by transection of the forebrain commissures. It is concluded that a unified and stable representation of visual space is produced by circuitry with a remarkable capacity for reorganisation.
[Supported by NIH EY12032.]

◆ **Neural basis of spatial encoding during eye movements**

F Bremmer (Department of Neurophysics, Philipps University Marburg, Renthof 7/202, D 35037 Marburg, Germany; e-mail: frank.bremmer@physik.uni-marburg.de)

Eye movements challenge the brain. While the image of external objects moves across the retina, we perceive the outer world as being stable. Yet, this perceptual stability is not complete. Numerous studies have recently shown that spatial perception is modulated during smooth tracking and during saccadic eye movements. The location of visual stimuli briefly flashed during smooth-pursuit eye movements is shifted in the direction of the pursuit. Mislocalisation during saccades depends on the exact experimental conditions. If saccades are performed in total darkness, all perceived locations are shifted in the direction of the saccade (shift). In ambient light conditions, all perceived locations are shifted towards the endpoint of the saccade (compression). In a recent psychophysical study we could show that spatial mislocalisations are observed also during reflexive optokinetic eye movements. Perceived locations are shifted in the direction of the slow eye movements. Yet, this shift is modulated during the saccade-like resetting phases. I briefly review the findings of our psychophysical study on reflexive eye movements in humans. Then I present neurophysiological data from recordings in posterior parietal cortex of monkeys that relate to the above-described psychophysical findings.

[Supported by Deutsche Forschungsgemeinschaft (DFG) and Human Frontiers Science Program (HFSP).]

◆ **Spatiotemporal changes in receptive fields around the time of saccades: Evidence from motion integration and form aftereffects**

D Melcher (Department of Psychology, Oxford Brookes University, Oxford OX3 0BP, UK; e-mail: dmelcher@brookes.ac.uk)

Visual perception does not begin afresh with each new fixation. Instead, what is perceived can be influenced by useful and predictive information from the previous fixation. Motion and form information is integrated across saccades, but the nature of this integration in space and time depends on whether the stimuli are spatiotopically or retinotopically matched. The properties of visual integration suggest a progressive transformation from retinotopic to eye-independent fields along the visual processing pathway, mediated by the updating of spatial maps in parietal cortex.

Monday

- ◆ **Integration of presaccadic and postsaccadic information is mediated by postsaccadic landmarks**
H Deubel, C Koch, W X Schneider (Department of Psychology, Ludwig Maximilians University, Leopoldstrasse 13, D 80802 Munich, Germany; e-mail: deubel@psy.uni-muenchen.de)

How does the visual system achieve a continuous and stable percept of the visual world, despite the gross changes of its retinal projection that occur with each saccade? We argue that an important factor of space constancy is formed by the reafferent information, ie the visual display found when the eyes land. We studied how presaccadic information interacts with the post-saccadic visual information. Subjects detected changes of location or, in other experiments, of simple visual properties of objects which occurred during goal-directed saccades. We determined the effect of presence and of intrasaccadic displacements of task-irrelevant distractors on performance in these change-detection tasks. The results reveal that transsaccadic object perception and perceived visual stability depend critically on the visual pattern that is found after the saccade. If a postsaccadic pattern is present, it tends to replace the content of transsaccadic memory. Moreover, salient objects found in the visual field in a critical time period after saccade end serve as spatial references by which transsaccadic memory representations are anchored onto the postsaccadic reafference. We conclude that there is no need for precise extraretinal signals to achieve space constancy; rather, the visual system relies on the stability of the visual world. [Supported by the Deutsche Forschungsgemeinschaft (De 336/2).]

NEURONAL PROCESSING OF VISUAL IMAGE SIGNALLING: FROM NEURONAL CIRCUITS TO HUMAN PERCEPTION

- ◆ **Thalamocortical network during sleep and waking states: implication for sensory processing**
I Timofeev (Department of Anatomy and Physiology, School of Medicine, Laval University, Québec G1K 7P4, Canada; e-mail: Igor.Timofeev@phs.ulaval.ca)

Oscillatory activity is an emerging property of the thalamocortical (TC) system. The patterns and the dominant frequencies of these oscillations depend on the functional state of the brain. Depending on the phase of the oscillatory cycle, the cortical and/or thalamic neurons could be either in active or silent states. The active states in TC neurons during slow oscillation are associated with inhibition. Single ascending spikes arriving at TC neurons induce either EPSP in isolation or EPSP-spike sequences, while barrages of prethalamic spikes induce barrages of EPSPs leading to high-frequency spike trains at depolarised voltages and EPSP-low-threshold spike sequences at hyperpolarised voltages. The latencies of the firing largely depend on the membrane potential of TC neurons. Cortical network responds to the stimuli eliciting spikes, and does not respond to stimuli which do not elicit spikes in the thalamus. The unitary responses within neocortex are not reliable during active network states because of activity-dependent drop in $[Ca^{2+}]_o$. However, during active states, the cortical neurons are depolarised and remain close to the firing threshold, making efficient the oligosynaptic transmission. Thus, numerous gating mechanisms prevent TC network from efficient time-locked transmission of ascending information to the cerebral cortex, but intracortical dialogue during sleep is present.

[Supported by Canadian Institutes of Health Research and Natural Sciences and Engineering Research Council of Canada.]

- ◆ **Do we really see with three parallel streams?**
E Kaplan (Neuroscience, Mount Sinai School of Medicine, New York, NY 10029, USA; e-mail: ehud.kaplan@mssm.edu)

A central question in neuroscience is how the brain represents, encodes, and analyses the outside world. In the past quarter century the vision science community has been drawn to the notion that the visual system analyses the visual world by employing several independent neural streams, each served by a separate neuronal population with its own specialised cell type, connectivity pattern, and perceptual function. Examples include the X/Y/W streams of cats and the P/M/K streams of primates. Focusing on the primate visual system, I (i) review the data on which this dogma is based, (ii) discuss the criteria that such a theory must meet, and (iii) explore the difficulties that the parallel-streams hypothesis encounters in its collision with current anatomical, physiological, and psychophysical data. [Supported by NIH grant EY016371.]

- ◆ **How MT cells analyse the motion of visual patterns**
J A Movshon, N C Rust[¶], V Mante[§], E P Simoncelli[#] (Center for Neural Science [[#] also HHMI], New York University, 4 Washington Place, Room 809, New York, NY 10003, USA; [¶]McGovern Institute for Brain Research, Massachusetts Institute of Technology, Cambridge, MA 02139, USA; [§]Department of Neurobiology, Stanford University, Stanford, CA 94305, USA; e-mail: movshon@nyu.edu)

Neurons in MT (V5) are selective for the direction of visual motion. In addition, many MT neurons are selective for the motion of complex patterns independent of their component orientations—a

behaviour not seen in earlier visual areas. We show that the responses of MT cells can be captured by a linear model that operates not on the visual stimulus, but on the afferent responses of a population of nonlinear directionally selective V1 complex cells. We fit this cascade model to the responses of individual MT neurons to 'hyperplaid' made by summing six randomly chosen gratings. The model accurately predicts the separately measured responses of MT cells to gratings and plaids, and captures the full range of pattern motion selectivity found in MT. Cells that accurately signal pattern motion are distinguished by having broadly tuned excitatory input from V1, strong motion opponent suppression, and a tuned normalisation at the V1 stage that may correspond to suppressive inputs from the surround of V1 cells.
[Supported by NIH and HHMI]

◆ **Neuronal mechanisms of recognition of local features of surfaces of visual objects**

N F Podvigin, T V Bagaeva, E G Yakimova, D N Podvigina (Pavlov Institute of Physiology, Russian Academy of Sciences, nab. Makarova 6, 190034 St Petersburg, Russia;
e-mail: podvigin@yandex.ru)

Electrophysiological studies of mechanisms involved in recognition of the shape of surfaces of visual objects revealed new properties of LGN neurons. These neurons are sensitive to the magnitude of a brightness gradient and orientation of its vector in the test stimulus, the number of impulses (n) depending on these two parameters. Coefficient C , representing orientation selectivity (OS) of a neuron, was computed: $C = (n_{\max} - n_{\min})/n_{\max}$, where n_{\max} and n_{\min} are n values in responses to preferred and non-preferred orientations of gradient vector. C varied from 0.2 to 0.91. The mean value of C (53 neurons) was equal to 0.55 ± 0.20 (Podvigin et al, 2001 *Neuroscience and Behavioral Physiology* 31 657–668). In another series of experiments, each neuron was tested by both light bars and brightness gradients with different gradient vector directions. All 37 analysed cells showed OS both to bar orientation and to the vector direction. For the bars $C = 0.51 \pm 0.06$; for the brightness gradient $C = 0.60 \pm 0.05$ ($p < 0.05$). By using test stimuli which reproduce real surface features of visual objects we revealed two new properties of LGN neurons: (i) their sensitivity to brightness gradient parameters, and (ii) complex OS both to binary (bars) and gray-scale (gradient) fragments of visual object surfaces.

[Supported by Russian Foundation for Basic Research (project 05-04-48067) and the Department of Biological Sciences of the Russian Academy of Sciences.]

◆ **Dynamic coding of image features in primary visual cortex**

V Dragoi (Department of Neurobiology and Anatomy, University of Texas-Houston Medical School, Houston, TX 77030, USA; e-mail: v.dragoi@uth.tmc.edu)

It is increasingly being realised that information processing in cerebral cortex depends not only on the nature of the incoming stimuli, but also on the state of neuronal networks at the time of stimulation. In primary visual cortex (V1), the ongoing activity of individual neurons is usually regarded as noise, and is assumed to be independent across cells. Whether and how ongoing activity influences the coding of visual features by individual neurons and networks is poorly understood. I investigate here whether orientation coding by neurons in the V1 of behaving monkey depends on neuronal activity before stimulus presentation. Hence, I examined the relationship between neuronal activity in the 300 ms period before and 300 ms period after stimulus onset, after grouping responses depending on the level of pre-stimulus activity in each trial. I found that the level of pre-stimulus activity is positively correlated with the signal-to-noise ratio, but negatively correlated with the orientation discrimination performance and strength of orientation tuning. Thus, high spontaneous states allow better stimulus detection, whereas low spontaneous states allow better stimulus discrimination. These results indicate that the ongoing activity of individual neurons dynamically interacts with incoming stimulus representations in V1 to influence image coding.

[Supported by Pew Scholars Program and James S McDonnell Foundation.]

◆ **Synchrony and firing rate in signalling processes of neurons in the cat primary visual cortex**

A Nemri, N Ghisovan, S Shumikhina, S Molotchnikoff (Department of Biological Science, University of Montréal, Montréal, QC H3C 3J7, Canada;
e-mail: abdellatif.nemri@umontreal.ca)

In spite of the multitude of local features forming an image (object), the visual system attains a coherent perception. It has been proposed that the latter is achieved by synchronised activity between cells, creating thus a unique neuronal assembly. Our aim was to test this hypothesis further. The experiments were carried out on anaesthetised cats prepared for electrophysiological recordings. One or two arrays of four electrodes were lowered in area 17. Two pools of cells were selected, characterised for their RF properties and simultaneously recorded. Individual

Monday

cells were sorted out offline. In the first set of experiments we compared the responses to direction of motion. Results revealed that when two neurons were excited by stimuli moving in the same direction, their synchrony was weaker than when the directions were convergent, while the firing rates remained unchanged. In a second set of experiments, neurons with specific orientation tuning properties were adapted to a non-optimal orientation. Resulting shifts in tuning curves were observed. Synchronisation strength before and after adaptation was compared for both the original and acquired optimal orientation. A decrease in synchrony was observed for the adapting orientation. Overall, these findings suggest that synchronisation strength reflects the image configuration.

◆ **What happens to visual cortex when it no longer receives visual input: Inter-modal plasticity in humans and rats**

F Lepore, M Lassonde, P Voss, F Gougoux, J-P Guillemot, P Belin, M Piché, R Zatorre (Department of Psychology, Centre de Recherche en Neuropsychologie et Cognition [CERNEC], Université de Montréal, CP 6128 Succ. Centre-ville, Montréal, Québec H3C 3J7, Canada; e-mail: franco.lepore@umontreal.ca)

Numerous studies have shown that blind human subjects are super-performing in numerous auditory tasks and recruit visual cortex during task execution. We demonstrated earlier that they are better than sighted subjects in sound localisation in near and far space and in pitch discrimination. We used a number of approaches to determine whether the increase in neural mass, resulting from the recruitment of visual cortex, is in fact responsible for this supra-normal behaviour. We showed, using positron emission tomography imaging, that there is a strong positive correlation between localisation performance and visual-cortex activation. Using transcranial magnetic stimulation, we demonstrated that inactivating visual cortex decreased performance in 'visual' pattern recognition with a prosthesis for substituting vision by audition. However, in a higher-order auditory task, namely, listening to vocal vs non-vocal complex sounds, fMRI showed that it is intramodal plasticity that operates here: blind subjects activate more strongly the voice areas in auditory cortex. We also looked at an animal model to see if cells in visual cortex actually respond to auditory sounds in enucleated rats and found that over one-third of the cells are activated by these stimuli.

[Supported by CIHR and NSERC.]

NOISE AND UNCERTAINTY

◆ **M V Lomonosov's optical works and limit of visual perception**

M M Miroschnikov, Y E Shelepin (Russian State Optical Institute, Pavlov Institute of Physiology, Russian Academy of Sciences, nab. Makarova 6, 199034 St Petersburg, Russia; e-mail: yshelepin@yandex.ru)

Lomonosov (1711 – 1765) is the pioneer of trichromatic theory of vision and wave theory, but in Russia Lomonosov's efforts are associated with the technology of silicates and glass, and original telescopes. The matter of making optical coloured glasses in Russia began by Lomonosov's cast smalts, molded smalts for mosaic. The colour and pixelisation of Lomonosov mosaic needs a spatial analysis. In our talk we concentrate on Lomonosov developing the night-viewing telescope. On the 13.05.1756 at an academic assembly Lomonosov gave a speech: "About machine for concentrating of the light". And on the 19.01.1758 he published the paper "Physical problem of night-viewing telescope". This refractive telescope was made by opticians I Belyaev and N Chizhov with a wide objective and small-diameter ocular lens. The first Russian polar expedition of Captain V Chichagov in 1764 – 1765 used six good-quality telescopes, three of them being Lomonosov's night-viewing ones. Lambert described a night-viewing telescope only in 1772. Lomonosov's next step was made in 1762, when he developed an original reflector telescope, a prototype of Hershel's telescope described only in 1789. For our meeting the discussion of Lomonosov's night-viewing telescope has not only historical interest; it is very close to actual correlation between MTF function, photon noise, scotopic vision, and signal-to-noise ratio.

◆ **ROC curves refute an unequal-variance account of search asymmetry**

R F Murray (Centre for Vision Research, York University, 4700 Keele Street, CSEB 0009, Toronto, Ontario M3J 1P3, Canada; rfm@yorku.ca)

It is easier to detect a C among O's than vice versa. One proposed explanation for such search asymmetries is that the internal responses generated by the two targets have different variances. We tested this explanation by measuring ROC curves. In experiment 1, three observers detected a C among Os, and vice versa. We measured 75% contrast thresholds for target detection at set sizes 1, 2, 4, and 8. In experiment 2, the same observers discriminated between C and O at contrast threshold, on a six-point confidence rating scale. We used the rating responses to generate ROC

curves. In experiment 1, thresholds were almost independent of set size for target C, but rose rapidly with set size for target O, demonstrating a strong search asymmetry. In experiment 2, ROC curves were slightly asymmetric, but the direction of asymmetry indicated that the variance of the internal response was greater for O than for C. This finding is qualitatively inconsistent with the unequal-variance account of search asymmetry, which requires that the easier target, in this case the letter C, has the greater variance. We consider what alternative theories of visual search are consistent with these results.

[Supported by the Natural Sciences and Engineering Research Council of Canada.]

◆ **Contrast discrimination: Second responses unambiguously reveal the relationship between the mean and variance of visual signals**

J A Solomon, M J Morgan (Department of Optometry and Visual Science, City University, Northampton Square, London EC1V 0HB, UK; e-mail: J.A.Solomon@city.ac.uk)

To explain the relationship between first- and second-response accuracies in a detection experiment, Swets et al (1961 *Psychological Review* **68** 301–340) proposed that the variance of visual signals increased with their means. However, both a low threshold and intrinsic uncertainty produce similar relationships. So we decided to measure the relationship between first- and second-response accuracies for contrast discrimination. Results obtained with suprathreshold contrasts would not be susceptible to contamination by a low threshold or intrinsic uncertainty. At detection threshold, our results confirm Swets et al's finding: second-response accuracies are lower than predicted by a simple signal-detection theory, without increasing variance, a low threshold or intrinsic uncertainty. At suprathreshold contrasts, our results are qualitatively different. A model that allows the variance of visual signals to increase with their mean cannot produce a significantly better fit to our data than a constant-variance model.

◆ **Neural oscillations and illusory jitter**

D H Arnold, K Amano¶, T Takeda¶, A Johnston§ (School of Psychology, University of Queensland, Australia; ¶Department of Complexity Science and Engineering, University of Tokyo, Tokyo, Japan; §Department of Psychology, University College London, London, UK; e-mail: darnold@psy.uq.edu.au)

Moving borders defined by small luminance changes (or colour) can appear to jitter at a characteristic frequency when they are placed in close proximity to borders defined by large luminance changes (Arnold and Johnston, 2003 *Nature* **425** 181–184). Using psychophysical techniques, we have shown that illusory jitter can be generated when these different motion signals are shown selectively to either eye—implicating a cortical locus for illusory jitter generation. Using magnetoencephalography (MEG) to record brain activity, we have also found that brain oscillations, of the same frequency as the illusory jitter rate, are enhanced when illusory jitter is experienced. This does not occur when observers are exposed to either isolated motion signals defined by small luminance changes (or colour) or to physical jitter of the same frequency as the illusory jitter, suggesting that the enhanced brain activity is related to illusory jitter generation rather than to jitter perception per se. These observations support our hypothesis that this illusory jitter is generated in the cortex by a dynamic feedback circuit. We believe that this circuit periodically corrects for a spatial conflict generated by proximate motion signals that differ in perceived speed.

◆ **Time course of induced neural activity over long distances in the human visual cortex**

P O Mihaylov, V Manahilov, N Strang, W A Simpson (Department of Vision Sciences, Glasgow Caledonian University, Cowcaddens Road, Glasgow G4 0BA, Scotland, UK; e-mail: Petar.Mihaylov@gcal.ac.uk)

When observers are presented with a grey patch surrounded by dynamic noise, they perceive 'filling-in' of the artificial scotoma by the twinkling noise, which persists as an 'aftereffect' upon termination of the surround stimulation. (Ramachandran and Gregory, 1991 *Nature* **350** 699–702). We used VEPs to study the time course of neural activity within the artificial scotoma. Steady-state VEPs were elicited by a foveal Gabor patch of 4 cycles deg⁻¹ and SD = 1.5 deg. Artificial scotomas (4 deg in diameter) were centred at the fixation point and surrounded by dynamic luminance noise. Each trial contained a 14 s interval of surrounding noise followed by a 14 s noise-free interval. The surrounding noise reduced the VEPs up to 50%. The aftereffect also diminished the responses, which returned to the base line level about 10 s after the termination of the surround stimulation. This is in line with subjects observation of aftereffect duration. We obtained similar results in control experiment in which visual noise was superimposed on the test pattern. The results provide direct evidence that the perception of dynamic noise

Monday

during filling-in and aftereffect may be due to induced internal neuronal noise. These findings demonstrate long-range connections in the human visual network.

[Supported by ORSAS Award to PM.]

◆ **Rapid decisions in face of a natural variation of visual – motor uncertainty**

S Gepshtein, J Trommershäuser¶ (Laboratory for Perceptual Dynamics, Riken Brain Science Institute, 2-1 Hirosawa, Wako-shi, Saitama 351-0198, Japan; ¶ Department of Psychology, Giessen University, Otto-Behaghel-Strasse 10F, D 35394 Giessen, Germany; e-mail: sergei@brain.riken.jp)

Observers performed rapid movements towards visual configurations presented on a slanted touch-screen. The movements were from a central location to one of several concentric target locations. Each trial was initiated by touching the central location. The task was to touch the target region and avoid an adjacent penalty region within the following 600–700 ms. Hitting the target and penalty regions incurred positive and negative payoffs known to the observers. The shape of the distribution of landing points on the surface differed for different target locations: it was a function of both the direction of movement and surface slant. In agreement with predictions of a normative model of motor planning (Trommershäuser et al, 2003 *Journal of the Optical Society of America A* **20** 1419–1433), observers adjusted their aiming strategy for each location so as to maximise the overlap of the error distribution with the target region and minimise the overlap of the error distribution with the penalty region. To do so, observers had to take into account the different shapes of error distributions at different locations. This is evidence that the nervous system can represent the multiple uncertainties that occur in the interaction with the natural environment.

[Supported by Deutsche Forschungsgemeinschaft (DFG), Grant TR 528/1-2.]

◆ **The effect of spatial cues and illusory contours on visual detection**

V Salvano-Pardieu, B Wink¶, R Fontaine, A Taliencio§ (Laboratoire de Psychologie, EA 2114 [§ Département de Psychologie], Université de Tours, 3 rue des Tanneurs, BP 4103, F 37041 Tours Cedex 1, France; ¶ Psychology Group, Southampton Solent University, East Park Terrace, Southampton SO14 0YN, UK; e-mail: veronique.pardieu@wanadoo.fr)

Some authors have reported subthreshold summation with illusory contours (Dresp and Bonnet, 1995 *Vision Research* **35** 1071–1078; Poom, 2001 *Vision Research* **41** 3805–3816), whilst others have failed to observe such an effect (eg Salvano-Pardieu et al, in press *Perception*). Here, we address methodological differences between some of these studies. Ten participants detected a target line in four conditions: target between two dots; between two arrow-heads ('V'); between two pacmen; generating a half Kanizsa square; or between two pacmen of a complete Kanizsa square generated by four pacmen. A 2AFC (left or right of a central fixation cross) classical staircase procedure was used with four threshold calculations per condition. Analysis shows a significant effect of condition ($F_{3,27} = 8.0152$; $p < 0.001$). Detection in the dot condition was significantly better than in any of the other conditions. However, no significant difference was found between the 'V', half Kanizsa, and complete Kanizsa conditions. Thus, the presence of the illusory contour, in the two Kanizsa conditions, did not facilitate detection. This result is congruent with explanations of facilitation of detection in terms of differences in spatial uncertainty and mean luminance rather than subthreshold summation.

THEORY AND MODELS

◆ **Investigation of adaptation processes in computer vision systems, based on the equations of the order principle**

V A Bunyakov (Television System, Central Research & Development Institute of Robotics and Technical Cybernetics, Tikhoretsky pr. 21, 194064 St Petersburg, Russia; e-mail: bunyakov@rtc.ru)

Adaptation processes are essential for survival of living creatures. In nature, the process of adaptation can always be considered as a dynamical transition from the initial state to another one. A P Smirnov proposed a universal law, the order principle, according to which all transition processes in nature are described by the same equation, based on natural logarithm dependences. In computer vision, an adaptive system of pattern recognition consists of three levels of image processing: (i) detection of a region of interest; (ii) image segmentation and extraction of information about features; and (iii) pattern recognition itself. I propose that the same law can also be applied to artificial systems. There are two phases of information processing by the computer vision systems: an external action, which induces the adaptation process, and the system reaction, which implements the adaptation process.

- ◆ **Hardware motion detection implementation based on low-pass timing filtering and neural net**
E V Isaev, A S Blochina, A V Bakhshiev, A M Korsakov (State Scientific Center of Russia, Central R&D Institute for Robotics and Technical Cybernetics, Tikhoretsky pr. 21, 194064 St Petersburg, Russia; e-mail: Isaev-Egor@yandex.ru)

We developed hardware and software for a visual simulator for motion detection which can be used as an independent computer vision system for security purposes. Researches in this field are required for developing systems that have low noise level and high detection performance. The available approaches to motion detection use foreground mask building. In contrast, we exploit low-pass filtering and neural net for motion processing. To select objects that move with different speed we use an algorithm for building difference frames which is based on the responses of low-pass temporal filters with various time constants. Hardware implementation of the simulator allows us real-time motion detection.

- ◆ **Minimum requirements for useful artificial vision: Mobility and environment predictability**
K Chanderli, J Sommerhalder¶, A A Perez Fornos¶, A B Safran¶, M Flückiger, M Pelizzone¶ (Faculty of Psychology and Sciences of Education, University of Geneva, 40 boulevard du Pont d'Arve, CH 1211 Geneva, Switzerland; ¶Eye Clinic, Geneva University Hospitals, 24 rue Micheli-du-Crest, CH 1211 Geneva, Switzerland; e-mail: kchanderli@gmail.com)

Useful visual prostheses should provide sufficient information for the performance of simple tasks. We explored such minimum requirements for mobility using simulations of artificial vision in normal subjects. The tasks consisted of walking through an obstacle course in two different environments, distinguishable by their degree of predictability: either six specific objects within a circular 30 m circuit, or 50 poles randomly placed within a 16 m × 7 m surface. Pixelised images of the environment were projected on a restricted and stabilised retinal location (10 deg × 7 deg viewing window following the subject's eye movements). Performance was assessed while systematically varying the effective visual field projected in the viewing window and the pixel density (stimulus resolution). About 200 pixels distributed over an effective visual field of 33 deg × 23 deg convey enough visual information to allow for mobility in highly predictable environments. At least 500 pixels were necessary to reach adequate performances in less predictable environments. The 33 deg × 23 deg effective visual field also yielded the best performance. Mobility in unpredictable environments requires more than twice the visual information needed for moving in a predictable space. The minimum stimulus resolution ascertained for mobility in unpredictable environments is thus comparable with previously determined values for the reading task. [Supported by Swiss National Science Foundation, and Pro Visu Foundation.]

- ◆ **A multinomial processing-tree model of scene perception**
E Boloix (Department of Cognitive Psychology, Université de Provence, 29 avenue Robert Schuman, F 13621 Aix-en-Provence Cedex 1, France; e-mail: eboloix@up.univ-aix.fr)

Recent works on the modeling of visual attention have successfully simulated ocular behaviour of human observers performing a visual-search task on scenes. Unfortunately, these models do not account for the visual information that is represented in memory. This issue is crucial, since (i) previous attention does not guarantee that visual information is represented in memory, and (ii) the visual information that is represented in memory will guide subsequent behaviour. Here, a multinomial processing-tree model of the visual representation of scenes, when observers have to perform a task on visual scenes, is proposed. Multinomial models are substantively motivated models that provide a means of measuring latent cognitive processes from observable raw data. The aim of the current model aim is to determine what visual information is extracted, processed, and represented in memory when observers have to perform a complex task on the visual scenes. Furthermore, the model assesses and weighs up the cognitive processes underlying the visual representations of scenes under active viewing. The model has been tested and validated with empirical data. Results and implication of theories of visual perception are further discussed.

- ◆ **The pigment cycle in the invertebrate eye: new phenomenological model**
D-E Creanga (Faculty of Physics, Biophysics, and Medical Physics, University 'Al. I. Cuza', 11A blvd Carol I, RO 700506 Iasi, Romania; e-mail: dorinacreanga@yahoo.com)

The complex reactions related to rhodopsin transformations after light absorption until the generation of the electric response of the photoreceptor cell membrane are still in the attention of biophysicists since there are still intermediate aspects that have not been sufficiently clarified. The data provided by direct and indirect measurements carried out on the model eye of the invertebrate *Drosophila melanogaster* are useful in the understanding of the interconvertible photo-sensitive pigment dynamics. A new variant of the former model is proposed, which describes the xanthopsin–metaxanthopsin cycle considering the roles of the screening pigment and that of

Monday

the sensitising pigment. The whole transformation diagram could be composed of two main loops—a couple of differential equations being adequate for their quantitative description. The equation solution implies self-organisation phenomena within the reversible biochemical reactions triggered by light absorption in the photoreceptor cells.

◆ **A computational model for visual learning of affordance-like cues**

L Paletta, G Fritz, E Rome¶, G Dorffner§ (Institute of Digital Image Processing, Joanneum Research, Wastiangasse 6, A 8010 Graz, Austria; ¶ Fraunhofer Institute for Autonomous Intelligent Systems, Schloss Birlinghoven, D 53754 Sankt Augustin, Germany; § Österreichische Forschungsgesellschaft für Künstliche Intelligenz, Freyung 6, A 1010 Vienna, Austria; e-mail: lucas.paletta@joanneum.at)

There are human affordances that are explicitly innate through evolutionary development and there are affordances that have to be learned (Edwards et al, 2003 *Brain Cognition* **53** 495–502). In technical vision systems, affordance-based visual object representations are function-based and have so far been predetermined by heuristic engineering (Stark and Bowyer, 1995 *Image Understanding* **59** 1–21). In contrast, we propose that the selection of relevant predictive visual cues should be performed by machine-learning methodology, operating on the basis of a complete spectrum of perceptual entities. In particular, we investigate local gradient patterns in 2-D (SIFT features—Lowe, 2004 *International Journal of Computer Vision* **60** 91–110) in affordance cueing among other visual modalities, such as colour, shape, and 3-D information. Predictive features are then derived from attribute-based rules that are extracted from a decision-tree-based classifier. Decision trees are demonstrated to be capable to provide a predictive feature configuration for the representation of an affordance-like cue on the basis of an information theoretic framework. Experimental results successfully verify the conceptual framework from the viewpoint of an autonomous mobile agent that is engaged within a robotic system scenario.

◆ **Discrimination-induced misperception of motion**

M Jazayeri, J A Movshon (Center for Neural Science, New York University, 4 Washington Place, New York, NY 10003, USA; e-mail: mjaz@cns.nyu.edu)

When observers perform fine sensory discriminations, the most accurate sensory information comes from neurons tuned to stimulus values that are displaced away from the centre of the range being discriminated. Psychophysical and neurophysiological evidence suggests that observers base their decisions on these ‘displaced’ neurons. One way to do this is for the brain to weight signals from these neurons more heavily in computing the decision. If this is so, the unequal weighting might lead subjects systematically to misperceive the stimuli being discriminated. We tested this idea in a direction discrimination task, using moving random-dot stimuli, and found that observers indeed perceive the direction of these stimuli to be displaced away from the discrimination boundary. The pattern of these perceptual biases can be accurately described by a model that integrates the unbiased sensory responses with a performance-optimising displaced weighting profile. Our results suggest that this discrimination-induced misperception of motion is due to optimisation of the system in making perceptual judgments.

[Supported by NIH.]

◆ **Occipital–parietal interaction in incomplete pattern discrimination**

V A Fokin, G A Trufanov, A Sevostyanov, Y E Shelepin¶, A Harauzov¶, S V Pronin¶ (Military Medical Academy, Lebedeva 6, 194044 St Petersburg, Russia; ¶ Pavlov Institute of Physiology, Russian Academy of Sciences, nab. Makarova 6, 199034 St Petersburg, Russia; e-mail: vladfokin@mail.ru)

Our aim was to localise cortical areas involved in the processing of incomplete figures using fMRI. Stimuli were matrices composed of 64 Gabor gratings with equal (ordered) or random (disordered) orientation. The subjects’ tasks were (i) passive observation of the patterns with fixation on the screen centre, and (ii) active discrimination of order in the patterns. fMRI signals were elicited by the rotation of each grating in the matrix. During passive observation, ordered matrices caused activation in occipital lobes, disordered matrices activated not only occipital but also parietal lobes. We suppose that disordered patterns composed of gratings with several orientations activate neurons in extrastriate cortex with large receptive fields which overlap the entire matrix. On the contrary, ordered matrices activate neurons of striate cortex with small receptive fields which overlap a single grating in the matrix. The interaction mechanism between neuronal columns with receptive fields of the same orientation may amplify the fMRI response. These results demonstrate different activities of occipital and parietal areas during passive observation only. The instruction to discriminate ordered and disordered patterns evokes an additional

locus of activation localised in the prefrontal cortex, which, we presume, reflects the work of the central executive mechanism.

[Supported by RFBR 05-04-49032; RHSF 05-06-06085.]

ATTENTION, EYE MOVEMENTS, ACTION

◆ Levels of perception: New evidence from eye-tracking and brain-activity analysis

B M Velichkovsky (Department of Psychology, Dresden University of Technology,
D 01062 Dresden, Germany; e-mail: velich@psychomail.tu-dresden.de)

Current advances in eye tracking make it possible to elucidate components of visual information processing in their interaction, during continuous, real-life tasks. The results of several studies selectively directed to testing these components, ranging from midbrain to cortical pathways and prefrontal structures, are reported. The results disclose human eye movements as a common output of a number of evolutionary mechanisms. For instance, the exploration of static and dynamic visual scenes is mainly under control of dorsal and ventral pathways. While usually both these pathways are involved (their interaction being influenced by several factors), it is the ventral pathway that seems to drive 'attentive fixations' necessary for higher-order perception, such as identification of objects and events. As the next example, we describe two mechanisms (one fast and reflexive, the second slower and adaptive) that lead to a 'freezing' of visual fixations in response to sudden stimuli/events. Finally, at the top the hierarchy, one finds oculomotor processes, involved in self-referential perception. The monitoring of eye movements is a valuable addition to the methods of brain-activity analysis. Moreover, this strategy opens new applied perspectives for basic research in perception, such as (nearly) online explication of image-based decisions in medicine and the enhancing of transportation security.

◆ Where do we look when walking down the street?

F Cristino, R Baddeley (Department of Experimental Psychology, University of Bristol,
12A Priory Road, Bristol BS8 1TU, UK; e-mail: f.cristino@bristol.ac.uk)

We recorded seven videos of street scenes using a head mounted camera, and played these videos, together with six spatiotemporally bandpass filtered versions, to subjects whilst recording their eye movements. Using this large data set (24 million eye movements), we first attempted to determine the spatial and temporal frequency characteristics of the eye-movement generating system. Using a mixture modeling technique, we found the eye-movement system to be very broadly tuned, with a peak sensitivity around 7 Hz and $0.5 \text{ cycle deg}^{-1}$. We then analysed our data to find evidence for separate motion and spatial channels. Despite this being consistent with the physiology, fitting various probabilistic models to the data showed no evidence for separate channels. Strong evidence, instead, was found that the global determination of fixation is not determined by low-level features, with subjects fixating to similar locations when viewing differently filtered videos that shared no common features. They often fixated locations that, whilst behaviourally important, were essentially blank (having no image features). We conclude that, whilst low-level salience may be important in determining the local localisation characteristics of eye movements, processes at a much higher level are responsible for global directing of eye movements.

[Supported by an EPSRC grant (REVERB)]

◆ How much attention is needed for saccadic programming?

A Montagnini, E Castet (Institut de Neurosciences Cognitives de la Méditerranée, UMR 6193,
CNRS-Aix-Marseille University, 31 chemin Joseph Aiguier, F 13402 Marseille Cedex 20,
France; e-mail: Anna.Montagnini@incm.cnrs-mrs.fr)

Although the presaccadic attentional enhancement at the saccadic goal is well established, Kowler et al (1995 *Vision Research* **35** 1897–1916) have shown that a part of attentional resources can be diverted from the saccadic target without a dramatic cost for saccadic accuracy. Our aim here is to spatiotemporally characterise this independent component of attention during saccadic preparation. With a Posner-type paradigm, we varied the probability (p) of presenting a perceptual target at the saccadic goal or opposite to it ($1 - p$). Thus, a situation of synergy ($p = 75\%$), neutrality ($p = 50\%$), or conflict ($p = 25\%$) arises between saccadic programming and the voluntary, independent attentional component. We took the ratio of orientation thresholds at the saccadic goal and opposite to it as a measure of the spatial specificity of attentional deployment. Perceptual performance was assessed either early or late (6 or 150 ms after saccadic cue onset) during the phase of saccadic preparation. Our results show that the effect of the probability bias on the spatial distribution of attention is prominent very early during saccade preparation. It is only in the late part of saccadic latency that the automatic influence of saccadic programming on perception becomes apparent.

[Supported by the PRA European network.]

Monday

◆ **De-activation of primary visual areas during the attentional blink**

M A Williams, T Visser¶, R Cunnington§, J B Mattingley# (McGovern Institute for Brain Research, Massachusetts Institute of Technology, Cambridge, MA 02139, USA; ¶Psychology and Computer Science, University of British Columbia, Canada; §Neuroimaging and Neuroinformatics, Howard Florey Institute [#School of Behavioral Science], University of Melbourne, Parkville, VIC 3052, Australia; e-mail: markaw@mit.edu)

When two objects are presented within about 500 ms, identification of the first is highly accurate, while identification of the second is significantly impaired. This second-target deficit, known as the attentional blink, reveals a fundamental limitation in our ability to allocate processing resources to sequential objects. We examined the locus of this processing limitation using fMRI to monitor activity in primary visual cortex during an attentional blink task. The results showed that identification of an initial target leads to a reduction in cortical activation for a trailing target. This demonstrates for the first time that object identification impairs allocation of low-level perceptual resources to temporally trailing sensory inputs.

◆ **Failure to reveal a global effect with distractor stimuli in the foveal region**

F Vitu, D Lancelin¶, A Jean§ (Laboratoire de Psychologie Cognitive, CNRS, Université de Provence, Centre St Charles, Bâtiment 9, Case D, 3 place Victor Hugo, F 13331 Marseille Cedex 3, France; ¶Laboratoire Psychologie de la Perception, CNRS FRE 2929, Université René Descartes, 71 avenue Edouard Vaillant, F 92774 Boulogne-Billancourt Cedex, France; §École des Psychologues Praticiens, Université Catholique de Paris, 26 rue du Montparnasse, F 75006 Paris, France; e-mail: Francoise.Vitu-thibault@up.univ-mrs.fr)

When distractor and target stimuli are simultaneously presented in peripheral vision, the initial saccade rarely goes to the target object; rather, the eyes land at an intermediate location between distractor and target. This very robust phenomenon is referred to as the global effect. In the present studies, we show that the effect fails to occur if distractor stimuli fall within the foveal region. On each trial, a saccade target (the central letter of a meaningless letter string) was presented in the right periphery while the distractor (an x-letter string of variable length) was presented in the ipsilateral foveal region. Only distractor stimuli extending beyond a foveal region of 1.1 deg deviated the eyes in a centre-of-gravity manner. Shorter distractors favoured the execution of short-latency saccades that kept the eyes within the distractor region; alternatively, they inflated the latency of larger saccades directed towards the target. The present findings suggest spatiotemporal discontinuities in the pattern of activity across the salience map. Implications for models of saccade generation are discussed.

◆ **Two distinct attentional mechanisms revealed by the third-order motion paradigm**

C-H Tseng, G Sperling¶ (Institute of Cognitive Science, National Cheng-kung University, Tainan, Taiwan, ROC, and Department of Cognitive Sciences [¶] and Department of Neurobiology and Behavior, and the Institute for Mathematical Behavioral Sciences, University of California, Irvine, CA 92697-5100, USA; e-mail: CH_Tseng@alumni.uci.edu)

The ambiguous third-order motion paradigm is a sensitive measure of feature-based attention. The motion display contains two competing directions associated with two colours (red and green), and observers' final percept is consistent with the direction associated with the stronger colour. In the current study, we used the same motion paradigm to study the dynamics of attention. In a block of 400 trials, observers followed the cue prior to each trial to shift their attention from red to green or vice versa every N trials ($N = 1, 50, 100, 200$). They reported their perceived direction. Trials in which subjects attended to red were averaged separately from attend-to-green trials. For all observers, the instructions to attend to a colour altered their motion perception, equivalent to increasing the relative physical saturation of the attended colour by 10% to 20%, only half that obtained by prolonged attention in previous studies. This effect was consistently observed in all conditions, even when observers had to shift attention every other trial ($N = 1$). The distinct temporal dynamics and persistent duration suggest there are different neural substrates involved in these two attentional mechanisms.

[Supported by AFOSR, Life Science Directorate, Visual Information Processing Program.]

◆ **Behavioural and electrophysiological evidence for selective visual processing during the preparation of saccade sequences**

H Deubel, D Baldauf (Department of Psychology, Ludwig-Maximilians-Universität, Leopoldstrasse 13, D 80802 Munich, Germany; e-mail: deubel@psy.uni-muenchen.de)

We studied the deployment of visual attention during the preparation of saccade sequences. Participants performed a sequence of two or three saccades to circularly arranged targets. A secondary task consisted in the discrimination of tachistoscopically presented target letters

(‘E’ and mirror-‘E’). The data show superior discrimination performance at all saccade goals of the impending sequence. Discrimination is close to chance level at the movement-irrelevant positions, even at the intermediate location between two goals of the eye-movement sequence. It can be concluded that, during the preparation of a sequence of saccades, attention is allocated in parallel to all movement goals, and is spatially divided among noncontiguous target locations. In a follow-up EEG experiment a dot probe paradigm was used to provide physiological evidence for the parallel selection of multiple movement goals. Participants executed a movement sequence to two out of three possible goal positions. During movement preparation, a dot was flashed either at one of the movement goals, or at the third, movement-irrelevant position. The data reveal that the N1-component induced by the dot is enhanced if the dot is flashed at any of the movement goals, indicating that both are attended in parallel well before sequence onset. [Supported by the Deutsche Forschungsgemeinschaft (De 336/2).]

COLOUR PROCESSING AND COLOUR CONSTANCY

- ◆ **Amacrine cell contributions to red – green opponency in central primate retina: A model study**
D S Lebedev, D W Marshak¶ (Laboratory of Sensory Informations Processing, Institute for Information Transmission Problems, 19 Bolshoi Karetnyi, 127994 Moscow, Russia; ¶ Department of Neurobiology and Anatomy, University of Texas Medical School, 6431 Fannin Street, Houston, TX 77030, USA; e-mail: lebedev@iitp.ru)

To investigate the contributions of amacrine cells (ACs) to red – green opponency, a linear computational model of the central macaque retina was developed, based on a published cone mosaic. In the model, ACs of ON and OFF types receive input from all neighbouring midget bipolar cells of the same polarity, but OFF ACs have a bias toward M-centre bipolar cells. This might arise owing to activity-dependent plasticity because there are midget bipolar cells driven by S cones in the OFF pathway. The model midget ganglion cells receive inputs from neighbouring ACs of both types. As in physiological experiments, the model ganglion cells showed spatially opponent responses to achromatic stimuli, but they responded to cone isolating stimuli as though centre and surround were each driven by a single cone type. Without AC input, L and M cones contributed to both the centres and the surrounds of model ganglion cell receptive fields. According to the model, the summed AC input is red – green opponent even though individual ACs are practically unselective. A key prediction is that GABA and glycine depolarise L OFF and M ON central midget ganglion cells; this may be reflected in lower levels of the chloride transporter KCC2 in their dendrites. [Supported by the Biological Sciences Department of RAS, Programs 2004-2006 (for DL).]

- ◆ **A spatially organised representation of colour in macaque primary visual cortex**
Y Xiao, A R R Casti, J Xiao¶, E Kaplan (Department of Neuroscience, Mount Sinai School of Medicine, Box 1012, 1 Gustave L Levy Place, New York, NY 10029, USA; ¶ Department of Biology, City College of the City University of New York, New York, NY 10031, USA; e-mail: youping.xiao@mssm.edu)

The representation of colour in the primary visual cortex (V1) of macaques has been studied extensively at the level of single units. However, it is unclear how the colour of a given stimulus is represented by the spatial pattern of the neural response across V1. We studied the responses of V1 to spatially uniform colours using optical imaging of intrinsic signals. We found that each colour activated an array of patches in V1, and that the patches elicited by different colours largely overlapped with each other. However, the peak locations of these patches were determined by the stimulus hue. The peaks associated with various hues form clusters, in which spatially close peaks are associated with perceptually similar hues. Each cluster represents a full gamut of hue in a small cortical area (< 300 µm across), and is located either inside or at the edge of a cytochrome oxidase blob. Our results suggest that, like other visual features such as orientation, hue is also represented orderly across V1. The orderly organised hue maps in V1, together with the hue maps in V2 that we have discovered recently (Xiao et al, 2003 *Nature* **421** 535 – 539), are likely to play an important role in hue perception.

[Supported by grants from NIH (EY16371 and EY 01867), Fight for Sight, and Research to Prevent Blindness, Inc.]

- ◆ **Perceiving colour at a glimpse: A bias towards changes near fixation**
E Brenner, J J M Granzier, J B J Smeets (Faculty of Human Movement Sciences, Vrije Universiteit, Van der Boechorststraat 9, NL 1081 BT Amsterdam, The Netherlands; e-mail: e.brenner@fbw.vu.nl)

We used classification images to examine whether certain parts of a surface are particularly important when judging its colour, such as its centre, its edges, or where one is looking. The scene consisted of a regular pattern of square tiles with random colours located along a short

Monday

line in colour space. Targets defined by a square array of brighter squares were presented for 200 ms. The colour of the target's tiles was biased by an amount that led to about 67% of responses being correct. Subjects fixated a point that fell within the target's lower left quadrant and reported each target's colour. Subjects tended to report the colour of the tiles near the fixation point. When coloured tiles were also presented before (and after) target presentation they had the opposite effect, indicating that the change in colour is critical. The influence of the colour of the tiles reversed at the target's border, but the colour at the border itself was not particularly important. These findings suggest that when judging surface colours during short 'glimpses' between saccades, temporal comparisons may be at least as important as spatial ones.

◆ **Colour constancy as measured with the partial colour matching (PCM) method**

L L Beattie, A D Logvinenko (Department of Vision Sciences, Glasgow Caledonian University, 70 Cowcaddens Road, Glasgow G4 0BA, Scotland, UK;

e-mail: lesley.beattie@gcal.ac.uk)

Colour constancy is usually measured by the asymmetric colour matching technique which has two major shortcomings. First, it implies changing the surface reflectivity which is hard to implement; second, an exact match of two surfaces lit by different lights is impossible to achieve. We use a new method which is free of these disadvantages. This partial colour matching (PCM) aims at describing colour appearance in terms of unique hues. Observers were asked to decide whether two Munsell papers have a common component hue. Those which do are said to partially match each other. The largest set of papers all of which partially match each other is called a chromaticity class. A chromaticity class consists of all papers which contain a particular component hue. The number of chromaticity classes shows how many component hues observers employ in their decision making. For four observers (all normal trichromats), twenty-two Munsell chips were tested under five illuminations (neutral, blue, green, red, and yellow). We found that although the colour appearance of Munsell papers changed with illumination, the chromaticity classes remained almost constant. Moreover, the component hue content of each paper remained relatively unaltered considering changes in illumination. Thus, the PCM technique reveals nearly perfect chromatic constancy.

[Supported by a grant from the Wellcome Trust GR068672MA.]

◆ **Do we discount or ignore illumination?**

J J McCann (McCann Imaging, 161 Claflin Street, Belmont, MA 02478, USA;

e-mail: mccanns@tiac.net)

Changes in the spectral composition of illuminants produce small, but consistent, departures from perfect colour constancy. These departures from perfect constancy provide a signature of the mechanism. We used a constant set of coloured papers in 27 different spectral illuminants. [All possible combinations of 3 intensities (1, 2, and 4 LEDs) for wavelengths 455, 530, and 625 nm]. Observers matched a gray, a purple, and an orange paper in each illuminant to chips in a Munsell book in constant spectral illumination. If we discount illumination, we need first to identify it. Departures from perfect constancy are held to be incomplete adaptations to each illuminant. The pattern in colour space of these departures should follow the pattern of illuminants. If, instead, we ignore the illumination and build the colour appearance from spatial comparisons (ratios), then changes of illumination affect equally both the numerator and the denominator of these spatial ratios. The overlap of cone spectral sensitivities creates chromatic crosstalk, which, in turn, affects spatial ratios for colourful papers, but not for grays. If we ignore illumination, then the signature of departures from constancy should vary with the reflectances of the papers, not the illuminants. Observer matches confirm the second, spatial-reflectance, hypothesis.

◆ **Illumination difference between two scenes does not enhance colour constancy**

J J M Granzier, J B J Smeets, E Brenner (Faculty of Human Movement Sciences, Vrije Universiteit, Van der Boechorststraat 9, NL 1081 BT Amsterdam, The Netherlands; e-mail: j.granzier@fbw.vu.nl)

Colour constancy involves correctly attributing a bias in the colour of the light reaching your eyes to the illumination, and therefore compensating for it when judging surface reflectance. But not all biases are caused by the illumination, and surface colours will be misjudged if a bias is incorrectly attributed to the illumination. Evidence from within scenes (highlights, shadows, gradients, etc) could help determine whether a bias is likely to be due to the illumination. To examine whether colour constancy relies on such evidence we asked subjects to match two surfaces on differently coloured textured backgrounds. With backgrounds on separate screens, subjects attributed only a modest part of the bias to the illumination. When simulated to give the impression of a single scene with an additional lamp at one side as seen through two (real)

windows, or when there was a real object illuminated to produce the same colour, the results were very similar. Showing each part to one eye, so that each eye could adapt independently, did have a clear effect of the illumination. We conclude that adaptation is more important for colour constancy than is a sophisticated analysis of the possible illumination.

◆ **Contextual effects of familiar object colours on colour perception**

A C Hurlbert, Y Ling (Institute of Neuroscience, School of Biology and Psychology, University of Newcastle, Henry Wellcome Building, Framlington Place, Newcastle upon Tyne NE2 4HH, UK; e-mail: anya.hurlbert@ncl.ac.uk)

Hering in 1874 suggested that the memory colours of familiar objects may influence their immediate perceived colour, as well as exert an indirect effect on the overall scene perception. Given the inherent ambiguity of the illumination colour, it may be that familiar objects with diagnostic colours serve as references against which other object colours are calibrated. We manipulated the colours of real, solid objects using our 'illumination box' (Ling and Hurlbert, 2004 *Journal of Vision* 4 721–724). Forty observers viewed arrays containing a test object (dome or familiar fruit) and a 'contextual' object (fruit or rectangular patch). We varied the colours of all objects systematically between trials. After a masking interval, the observers selected the best match to the remembered test object's colour from six alternatives, under the same (memory) or changed illumination (constancy). The 'contextual' object's colour significantly influenced the test object colour matches. For example, when the contextual object was a yellow banana, the remembered test object colours were more bluish than when the contextual object was a yellow patch, for both memory and constancy tasks. We hypothesise that the memory colour of the 'contextual' object biases the observer's estimate of the illumination colour.

[Supported by Unilever plc.]

◆ **Age-related changes of colour constancy**

A M C Werner, A Ehmer¶ (Centre for Ophthalmology, Institute for Ophthalmic Research, University of Tübingen, Roentgenweg 13, D 72076 Tübingen, Germany; ¶ University of Applied Sciences Jena, SciTech Department, Carl Zeiss Promenade 2, D 07745 Jena, Germany; e-mail: annette.werner@uni-tuebingen.de)

The degree of colour constancy can vary considerably between observers. Here we ask how the performance of colour constancy depends on the age of observers. We tested sixty subjects, aged between 15 and 75 years; all had normal or corrected-to-normal visual acuity and normal colour vision (Cambridge Colour Test). Colour constancy was measured for the achromatic appearance of a hexagonal testfield ($2.4 \text{ deg} \times 2.4 \text{ deg}$, $L_{\text{test}} = 19.3 \text{ cd m}^{-2}$, $u' = 0.197$, $v' = 0.468$ under standard condition), which was presented on a multicoloured background ($18 \text{ deg} \times 18 \text{ deg}$, equal luminance and mean chromaticity as the testfield). Using a hue cancellation method, we measured colour constancy for simulated illumination changes along an equiluminant L–M or S–(L + M) axis. For 60 s adaptation time, the overall performance in colour constancy (80%–90%) was independent of the age of the observers. For 5 s adaptation, colour constancy performance dropped with increasing age and most significantly for illumination changes along the S–(L + M) axis. The results cannot be explained by age related changes of the optical media of the eye or a general loss in sensitivity. Instead, the results indicate changes in the temporal dynamics of the neuronal process which contribute to colour constancy.

POSTER SESSION

BINOCULAR AND STEREO VISION

◆ **Does stereopsis reflect different degree of binocular interaction in amblyopia?**

I M Boychuk (Institute of Eye Diseases and Tissue Therapy, Frantsuzsky blvd 49/51, 65061 Odessa, Ukraine; e-mail: iryna54@mail.ru)

Every case of amblyopia has traits which belong to the different etiological types of amblyopia and it can be difficult to decide which type is present and what kind of treatment to apply. Here an attempt is made to classify amblyopia on the basis of the monocular function of both eyes and binocular performance. 332 children (aged 5–10 years) with unilateral strabismic amblyopia (120), anisometropic amblyopia (112), and refractive amblyopia (100) participated in the study. Monocular performance (26 indices) for both eyes and binocular functioning (6 indices) were evaluated by the statistical methods of cluster and multiple regression analysis with Statistics for Windows 98. Amblyopes were separated into three groups according to certain indices—critical flicker fusion, time of mesopic vision of amblyopic eye, and threshold of peripheral stereovision. Group I included amblyopes with decreased thresholds of central and peripheral stereovision; group II was characterised by the absence of central and decreased thresholds of

Monday

peripheral stereovision; both central and peripheral stereovision were absent in group III. The results are discussed in relation to known morphological changes which were found in monocular and binocular segments of visual cortex in experimental amblyopia and some clinical data on stereovision in amblyopic and strabismic patients.

◆ **Why a random-dot stereogram can induce stereopsis without any monocular cues**

T Z Wang (Department of Automation, Wuhan University of Technology, PO Box 125, East Campus, Wuhan University of Technology, Wuhan, 430070 China (PRC); e-mail: wtz21@yahoo.com.cn)

Random-dot stereograms (RDSs) demonstrate that binocular disparity on its own, without any monocular form cue, can induce stereopsis. In literature, disparity is defined as the position difference between a pair of semantic points, rather than a pair of physiological points. How to find a pair of semantic points before recognition is difficult, especially in an RDS. On the basis of analyses of diplopia, a new binocular visual model—a visual motor feedback—model is proposed. The model assumes that each binocular cell in the primary visual cortex receives light signals from two physiological corresponding dots on the retina, and outputs the difference of the two signals to downstream cells; the downstream cells then integrate outputs of all binocular cells and transmit the sum (the retina image difference) to extraocular motor neurons and optical components of the eye: the lens, cornea, vitreous humour, etc then control motion or adaptation to decrease the difference between the two images, and give rise to stereopsis. In the model, the item that is controlled is the difference between retina images other than the disparity. The model can reasonably explain why RDSs can induce stereopsis without any monocular cues, and also can explain the Fechner paradox and the Pulfrich depth illusions.

[Supported by NSFC No. 60275040.]

◆ **Binocular fusion limits in presence of colour contrast**

Y Loginovich, A Bulatov, A Bertulis (Department of Biology, Kaunas University of Medicine, Mickėvičiaus 9, LT 44307 Kaunas, Lithuania; e-mail: loginovich@vision.kmu.lt)

Panum's area in the fovea region was examined with paired three-dot stimuli organised in right-angle patterns displayed separately to each eye. One of the dots in the test stimuli was red or green, while the other two were white. All dots of the referent stimuli were white. The control paired stimuli formed of achromatic white dots were also used. The length of the sides of the stimuli was 10, 20, 30, or 40 min of arc. Subjects manipulated the panel keys and moved the colour end-dot of the test stimulus horizontally to the left or to the right and vertically up or down in 0.3 min of arc steps until reaching the fusion limits. The background luminance was 5 cd m⁻², the luminance of the referent dots was 15 cd m⁻², and the colour test-dot was isoluminant with the corresponding white dot of the referent stimulus. Panum's area was found to have the horizontal elliptic shape with the ratio of diameters roughly constant, 1 : 2 for red and green colours tested, but showed a tendency to be smaller than that measured with the achromatic white stimuli. The difference between the achromatic and chromatic fusion limits increased with the length of the stimulus sides.

◆ **A model for depth perception of 3-D images displayed by two stereoscopic displays at different depths**

K Uehira (Department of Network Engineering, Kanagawa Institute of Technology, 1030 Shimo-ogino, Atsugi-shi, Kanagawa 243-0292, Japan; e-mail: uehira@nw.kanagawa-it.ac.jp)

A 3-D display that uses two stereoscopic displays at different depths was studied, and it was found that two same-shaped 3-D images displayed at different depths by the two stereoscopic displays were fused into one 3-D image when they were viewed as overlapping. When the distance between the original perceived depths of the two 3-D images became greater than 10% of the distance between the observer and the screen, the two 3-D images did not fuse; however, their perceived depths differed from those that were originally perceived and they were closer than they had been at their original perceived depths. A model for 3-D image depth perception under conditions where the two 3-D images do not fuse is proposed. When the human visual system undertakes binocular matching in this model, it selects the wrong pair of edges. It sees the two edges of patterns displayed at different depths as the same edge, although they are the edges of different patterns. A simulation on the perceived depths of the two 3-D images with this model was carried out, and it was found that the perceived depth was accurately described by the proposed model.

◆ **Saccadic retinal shifts correlate with perceptual alternations in binocular rivalry**

L C J van Dam, R van Ee (Helmholtz Institute, Utrecht University, Princetonplein 5, NL 3584 CC Utrecht, The Netherlands; e-mail: L.C.J.vanDam@phys.uu.nl)

We have investigated the influence of local retinal image changes on the correlation between saccades and perceptual alternations in binocular rivalry. Subjects viewed classical $\pm 45^\circ$ grating stimuli and were asked to report perceptual alternations while we recorded saccades. By using grating stimuli, which, by definition, are repetitive in space, we distinguished saccades that did produce foveal image changes from saccades that did not. Our results reveal a strong correlation between specific foveal retinal image changes and percept dominance. We conclude that retinal image changes are crucial for the correlation between saccades and perceptual alternations and that (micro)saccades and, more specifically, their resulting retinal image changes play an important role in determining percept intervals in binocular rivalry.

◆ **Perception of multi-stable stereograms**

R Goutcher, P B Hibbard (School of Psychology, University of St Andrews, St Mary's College, South Street, St Andrews KY16 9JP, Scotland, UK; e-mail: rg70@st-andrews.ac.uk)

To solve the stereo correspondence problem, the visual system must make assumptions about the 3-D structure of objects in the world. However, the nature of these assumptions is unclear. The visual system may impose correspondence constraints based on biases for 3-D shape, disparity sign or disparity magnitude, or all three. Here we present a novel ambiguous stimulus, supporting four distinct percepts, which allows us to examine the contribution of these potential sources of matching bias. The stimulus contains multiple strips of periodic dot patterns, where the length of the period defines the available disparities. Owing to variation in period length between strips, our stimulus may be perceived as a convex or concave wedge, or as a top-near or top-far slanted plane. We biased observers' perception of the stimulus between these four solutions by modulating the luminance of the repeating patterns in each strip. Observers reported their perception in a 4AFC task. We find evidence of matching bias based on shape and disparity sign, together with large individual differences in matching preference. To account for our results, we propose a correlation-based model of disparity computation that includes prior biases for both shape and disparity sign.

[Supported by the BBSRC, UK, Grant No. C005260/1.]

◆ **Cortical binocularity in human stereoblindness: A study with functional magnetic resonance imaging**

A Jurcoane[¶], L Muckli[§], B Choubey[#], R Sireteanu (Department of Neurophysiology, Max Planck Institute for Brain Research, Deutschordenstrasse 46, D 60528 Frankfurt am Main, Germany; [¶] also Department of Biological Psychology, Institute for Psychology, Johann Wolfgang Goethe University, Mertonstrasse 17, D 60054 Frankfurt am Main, Germany; [§] also Brain Imaging Center, Johann Wolfgang Goethe University, D 60590 Frankfurt am Main, Germany; [#] Department of Engineering Science, University of Oxford, Parks Road, Oxford OX1 3PJ, UK; e-mail: jurcoane@mpih-frankfurt.mpg.de)

Our object was assessing the amount of binocularity at different cortical levels in subjects with normal or impaired stereopsis. We used a 3 T Siemens MRT Allegra scanner, with an event-related fMRI protocol. The stimuli were sinusoidal gratings of oblique orientation, flickering at 2 Hz, superimposed on a gray background, presented to the left or the right eye separately with the aid of a MR compatible goggle system. The gray background was used as baseline condition. In order to distract attention from the stimuli, an attention-control task was used. Analysis of fMRI data was performed with Brain Voyager QX. We tested ten normally sighted and three stereoblind subjects with alternating fixation. In the normally sighted subjects, we observed monocular adaptation in early visual areas, and monocular as well as interocular adaptation in the higher visual areas. In the stereoblind subjects, monocular adaptation with no interocular transfer was obtained in the extrastriate cortex. These results suggest that impaired stereopsis is related to a reduced interocular transfer of adaptation at higher levels in the cortical visual pathway. [Supported by grants to RS from the Deutsche Forschungsgemeinschaft (Si 344/17-1,2,3)]

◆ **Perceptual asymmetry in stereoscopic transparency**

I Tsirlin-Zaharescu, L M Wilcox, R S Allison (Centre for Vision Research, York University, 4700 Keele Street, Room 0009 CSB, Toronto, ON M3J 1P3, Canada; e-mail: inna@cs.yorku.ca)

Surface segregation in random-dot stereograms depicting overlapping surfaces depends on the relative density of elements in the two planes. The percept of transparency appears stronger when more elements are placed in the foreground than when they are located in the background.

Monday

To quantify this perceptual asymmetry, we measured the minimum disparity required for a coherent percept of transparency between two overlaid fields of sparse texture elements using a method of adjustment. While maintaining a fixed total element density, we varied the distribution of the elements between the front and back surfaces from 10 : 90 to 90 : 10. A significantly larger separation in disparity-defined depth was required to perceive transparency when the density in the background surface was larger than in the foreground surface. This dependence on the distribution of element density accounts for results that Gepshtein and Cooperman (1998 *Vision Research* **38** 2913–2932) attributed to crossed vs uncrossed disparities. We are conducting further experiments to test the hypothesis that our results reflect an asymmetry in the degree of inhibition between the two surfaces caused by assignment of blank regions to the background plane. [Supported by CRESTech and Premier's Research Excellence Award from the Province of Ontario.]

◆ **The influence of perceived surface slant of an ambiguous stimulus on vergence**

D A Wismeijer, R van Ee, C J Erkelens (Helmholtz Institute, Utrecht University, Princetonplein 5, 3584 CC Utrecht, The Netherlands; e-mail: d.a.wismeijer@phys.uu.nl)

We investigated the influence of perceived surface slant on vergence accompanying a saccadic movement. Using an ambiguous bistable slant rivalry stimulus, the subjects experienced one of two possible surface slants with opposite sign; one based on perspective foreshortening and the other one based on binocular disparity. The perspective cue specified a surface slant of $\pm 70^\circ$, while the slant specified by the disparity cue was (oppositely) $\mp 50^\circ$. A key aspect for our study is that the perceived sign of the surface slant is under voluntary control of the observer. Subjects were instructed to hold the slant percept specified by the perspective foreshortening. After a 4 s period of strict central fixation, subjects were instructed to make a saccade to the indicated edge of the surface at 10° of version. Subjects were able to comply with the instruction to hold the perspective-specified slant. Although the vergence at the landing position closely approximated the depth specified by the disparity cue, we conclude that, under the current conditions, there is no convincing evidence that voluntarily controlled perceived surface slant influences vergence.

◆ **An indispensable factor for 3-D illusory surface perception in binocular viewing**

H Zhang, M Idesawa (Graduate School of Information Systems, University of Electro-Communications, 1-5-1 Chofugaoka, Chofu-shi, Tokyo 182-8585, Japan; e-mail: hzhang@hi.is.uec.ac.jp)

We designed stereograms composed of binocularly paired random dots and binocularly unpaired random dots which were immediately flanking each other; then we observed them for three cases: including both the paired and the unpaired dots, including only the paired dots, and including only the unpaired dots. We found that illusory surfaces could be perceived in the first case, even though subjective contours could not be seen from each eye's view; in contrast they could not be observed in the second case, although the subjective contours could be seen. These perceptions demonstrate that the binocularly unpaired dots, but not the monocular subjective contours, are essential for perceiving illusory surfaces: which is consistent with Mather and Idesawa (1989 *Vision Research* **29** 143–146; 1991 *Japanese Journal of Applied Physics* **30** L751–L754). In addition, we found that the flanking position of the unpaired dots could change opaque and transparent properties of the illusory surfaces. In the third case, binocular rivalry occurred. Surprisingly, the unstable unpaired dots became quite stable when a suitable illusory surface was superimposed on them. We conclude that binocularly unpaired stimuli are indispensable for the formation of illusory surfaces and the visual system produces illusory surfaces in order to reduce binocular instability.

◆ **Observers perceptual states modulate ERP components differently in orientation and colour rivalry**

S Vesper, U Roeber, E Schröger (Institute of Psychology I, Leipzig University, Seeburgstrasse 14–20, D 04103 Leipzig, Germany; e-mail: veser@uni-leipzig.de)

When dissimilar stimuli are presented to the two eyes of an observer, these stimuli alternate. This phenomenon is known as binocular rivalry. In this study, orientation rivalry and colour rivalry were induced with isoluminant red/black and green/black gratings slanted to the left and right. We investigated electrophysiological responses following transitions from rivaling stimulation to non-rivaling stimulation. Depending on the prevailing percept reported by the observer, this transition could concern the eye which the stimulus was dominating (incompatible change) or suppressed (compatible change). For orientation rivalry, ERP differences between incompatible and compatible changes were found in P1, where percept-incompatible changes elicit a larger P1 peak than percept-compatible changes, whereas colour rivalry induced a percept-dependent modulation in the later ERP component, N1. Here, also percept-incompatible changes elicit larger amplitude than compatible changes. These results show that orientation rivalry yields earlier ERP differences than colour rivalry. Thus the solution of binocular rivalry depends on the properties of the stimulus as assumed in hierarchical models.

◆ **Fröhlich effect occurs beyond the level of binocular integration**

A Najafian¶, M Sanayei¶§, B Noudoost§ (¶ Neuroscience Research Group, Isfahan University of Medical Sciences, Isfahan, Iran; § School of Cognitive Sciences, Institute for Studies in Theoretical Physics and Mathematics [IPM], Tehran, Iran; e-mail: najafian@med.mui.ac.ir)

The initial position of a moving object is perceived ahead in its trajectory, which is known as Fröhlich effect (FE). FE is absent for a single rotating dot. Adding another similar rotating dot on the opposite side of its circular path restores the illusion. We used a dichoptic display to present stimuli to each eye separately and compared the determined FE for a single rotating dot and two rotating dots in different conditions. When a single dot was presented to both eyes simultaneously or to one eye, FE was absent. When two rotating dots were presented to both eyes simultaneously and FE was $11.24^\circ \pm 0.76^\circ$ (mean \pm SE). In another condition, we presented one rotating dot to the right eye and another dot to the left eye. Subjects now perceived two rotating dots although single dots were represented in the left and right early visual pathway. Measured FE in this condition was $13.47^\circ \pm 0.73^\circ$, similar to previous condition (Mann–Whitney, $p > 0.05$). Our results demonstrated that segregation of visual signals in the form of moving dots in the early visual pathway did not reduce FE. We conclude that activation of neurons responding to the information from both eyes is sufficient for FE to occur.

◆ **A comparison of objective and psychophysical measurements of step responses in disparity vergence eye movements**

S Jainta, W J Hoormann (Institute for Occupational Physiology, University of Dortmund, Ardeystrasse 67, D 44139 Dortmund, Germany; e-mail: jainta@ifado.de)

Dichoptic nonius lines have been questioned as valid indicators of dynamic-vergence eye movements. Therefore, we tested whether nonius lines flashed at controlled delays after a vergence step-stimulus may indicate a vergence response that agrees with objective recordings with the Eyelink II. In a mirror-haploscope, we presented convergent and divergent step-stimuli of 3 deg at a baseline vergence of 3 deg. The resulting initial vergence response for sixteen participants was estimated with nonius lines appearing for 80 ms at fixed delays of 0 ms, 100 ms, 200 ms, 300 ms, 400 ms, and 1000 ms after the step-stimulus. The vergence state reached at each delay was determined from the participants responses to the perceived relative position of the nonius lines. We calculated the maximal cross-correlation between the psychophysical measures at the first five nonius delays and the objective measures at the corresponding moments (taking into account a lag of the psychophysical relative to the objective measures): the median cross-correlation coefficient was 0.94 for convergence and 0.89 for divergence, suggesting a good agreement. The measured vergence state reached after 1000 ms was similar for convergent responses; however, the psychophysical method overestimated divergent responses by about 25%, on the average.

[Supported by the German Research Foundation (Deutsche Forschungsgemeinschaft/DFG 747/4-1).]

◆ **Viewing an object from above: the role of height in the visual field and object contour in the perception of 3-D shape**

P Scarfe, P B Hibbard (School of Psychology, University of St Andrews, St Andrews KY16 9JP, Scotland, UK; e-mail: ps18@st-and.ac.uk)

In many instances, 3-D shape from binocular disparity is systematically misperceived, consistent with the overestimation of near distances and the underestimation of far distances (Johnston, 1991 *Vision Research* **31** 1351–1360). Generally, the experimental stimuli in these situations have been presented at eye height, but in most natural tasks where binocular vision may be important, such as prehension, objects are viewed from above. This provides improved information in the form of (i) additional distance information from height in the visual field (Watt and Bradshaw, 2002 *Spatial Vision* **15** 253–254), and (ii) a view of the upper surface of the object and contour, which provides a disparity discontinuity across the edge of the object, that may be particularly useful in judging 3-D object shape. Here, we investigated the contribution of these cues in a standard apparently circular cylinder task. A view of the upper surface of the object and contour improved disparity scaling compared to when the only additional cue was height in the visual field; this, together with other research, suggests that the visual system uses both sources of information when scaling disparity.

◆ **Spot more differences with a synopter: Reducing interocular disparity increases participants ability to identify discordant regions in pictures and photographs**

R H Black, J Patel, R M Latto, R Lawson (School of Psychology, Eleanor Rathbone Building, University of Liverpool, Liverpool L69 7ZA, UK; e-mail: r.black@liv.ac.uk)

A synopter produces a scene of binocular parity, where the eyes see identical images. This has been shown to increase pictorial relief by removing convergence and disparity information from

Monday

nearby objects (Koenderink, 1998 *Philosophical Transactions of the Royal Society of London, Series A* **356** 1071–1086). We produced twenty 'spot the difference' diptychs each containing ten discordances specified by an image map. They were rear-projected for 60 s each onto a 2.0 m non-depolarising screen. Four viewing conditions were presented; 'binocular', 'monocular', 'simulated iconoscopic', and 'simulated synoptic' (generated by scaling horizontal image separation by $0.5\times$ and $1.0\times$ interpupillary distance). Twenty-eight participants wearing polarising glasses completed the study. Performance in the simulated conditions was dichotomised on the basis of the ability to fuse polarised images. A mixed 4×2 ANOVA showed a significant effect of viewing condition ($F_{3,72} = 10.855$, $p < 0.001$) and of viewing condition \times performance ($F_{3,72} = 21.275$, $p < 0.001$). A posteriori tests revealed that in both the iconoscopic and synoptic conditions fusers made less errors and identified more discordances (synoptic mean = 8.56 ± 3.33) than non-fusers (synoptic mean = 2.48 ± 1.43). Non-significant differences were found between fusers and non-fusers in both binocular and monocular conditions (binocular mean = 3.56 ± 1.12). Reducing interocular disparity and differential perspective appears to substantially enhance ability to notice new features in images.

◆ **Object information and binocular rivalry**

E W Graf, W J Adams (School of Psychology, University of Southampton, Shackleton Building, Highfield, Southampton SO17 1BJ, UK; e-mail: erich@soton.ac.uk)

A priority for the visual system is constructing 3-D surfaces from visual primitives. In order to do this, visual information from various stimulus attributes is combined to form a robust representation. Here, we investigate whether grouping mechanisms such as surface completion can influence relative dominance durations in binocular rivalry. Of interest is whether the shape of a surface region defined by one non-rivalrous visual attribute (disparity, structure-from-motion) can influence the dominance period of a separate, rivalrous region defined by another attribute (shading, perspective). Stimuli were created with corresponding dots in the two eyes' images creating an unambiguous 3-D surface (convex/concave bump, slanted plane). However, the central region in each eye's image contained a monocular 3-D shape cue (shading, perspective) specifying a surface either consistent or inconsistent with the non-rivalrous region. Observers reported which of the monocular images they perceived with button presses throughout each trial. For all variants of the stimulus, the monocular pattern consistent with the global surface percept enjoyed longer dominance durations.

◆ **Breaking up symmetry in depth**

M S Treder, P A van der Helm (Nijmegen Institute for Cognition and Information, Radboud University Nijmegen, PO Box 9104, NL 6500 HE Nijmegen, The Netherlands; e-mail: M.Treder@nici.ru.nl)

Symmetry detection is at its best when it can integrate symmetry pairs into a single object. The purpose of this study was to probe the symmetry detection mechanism by investigating the effect of redistributing parts of a symmetric pattern in depth. Subjects were asked to discriminate symmetric patterns from random-dot patterns. Stimuli consisted of three depth layers and were viewed through shutter glasses. The deepest layer always contained 'noise' (randomly positioned dots) and served as background for the two top layers which together formed either another noise pattern or a symmetric pattern. The noisy background layer was used to control task difficulty and to stimulate the subjects to make effective use of binocular disparity, as depth segregation of the stimulus could be used to separate noise from symmetry. The symmetric pattern was either presented in one of the two top layers or spread across these layers, by using a number of different manipulations. Presentation time was varied to explore when and how the symmetry detection mechanism reacts to stereoscopic depth information. Preliminary data suggest that depth information is available at presentation times of 300 ms or more, and that breaking up symmetry in depth interferes with the detection of symmetry.

◆ **The binocular oblique effect**

T Borra, I T C Hooze, F A J Verstraten (Department of Psychology – Experimental Psychology, Faculty of Social and Behavioural Sciences, Utrecht University, Heidelberglaan 2, NL 3584 CS Utrecht, The Netherlands; e-mail: t.borra@fss.uu.nl)

The oblique effect (the more precise perception of horizontal/vertical orientations compared to oblique orientations) depends on perceived object orientation for monocularly presented gratings with the simultaneous tilt illusion (Meng and Qian, 2005 *Vision Research* **45** 3402–3413). Does this finding transfer to dichoptically presented stimuli? In other words, is the oblique effect dependent on the physical orientation of left-eye and right-eye images or on the binocularly perceived orientation? To test this, observers were presented with a temporally separated dichoptic

reference and test stimulus and were instructed to adjust the orientation of the test stimulus to the reference stimulus. Three reference stimulus orientations were used: (i) 0° (both eyes); (ii) -20° (both eyes), and (iii) 20° (left eye) and -20° (right eye). This led to the following perceived orientations, 0° , -20° , and 0° , respectively. If the oblique effect is only dependent on the physical orientation of left-eye and right-eye images, one would expect standard deviations for the adjustments in conditions 2 and 3 to be similar. However, standard deviations for the third condition were lower than for the second condition and higher than for the first condition for each observer. This suggests that the oblique effect also depends on the perceived orientation for dichoptically presented stimuli.

◆ **Age dynamics of ocular dominance assessed in conditions of binocular rivalry**

N N Vasiljeva (Chuvash State Pedagogical University, ul. K. Marksa 38, 428000 Cheboksary, Russia; e-mail: gir@iitp.ru)

Dichoptically presented uniform light fields were used to evoke binocular rivalry. While the right eye of a subject was stimulated, his left eye was in darkness, and vice versa. In such conditions, subjects usually observed episodic darkening of the visual field that could be treated as a temporary prevalence of the eye 'stimulated by darkness' in the course of binocular rivalry. The difference in the number (N) of such dark intervals per minute (Δn) in conditions when only right and only left eye is stimulated could be taken as an index of eye dominance. In such conditions, we examined two hundred children aged 5–10 years and one hundred adults. The value of N varied from 0 to 15. The mean value of Δn appeared to increase with age systematically from about -0.8 in the youngest children to $+1.1$ in adults; the zero level was crossed at the age of 7.5 years. To explain the observed developmental changes in the average index of eye dominance, one could postulate that, in subjects with potential left-eye dominance, the asymmetry of ocular relations makes itself evident earlier than in subjects with potential right-eye dominance, but the resulting number of subjects with right-eye dominance is greater.

◆ **Mapping visual areas sensitive to binocular disparity with fMRI**

H Bridge, A J Parker¶ (FMRIB Centre, University of Oxford, John Radcliffe Hospital, Oxford OX3 9DU, UK; ¶ Department of Physiology, Anatomy and Genetics, University of Oxford, Parks Road, Oxford OX1 3PT, UK; e-mail: holly.bridge@physiol.ox.ac.uk)

fMRI studies indicate that human cortical visual areas respond to stereoscopic depth. We compared the mapping of cortical areas with binocularly correlated and anticorrelated stimuli. Anticorrelated stimuli excite disparity-sensitive neurons in the cortex but do not produce a sensation of depth. Five subjects were scanned at 3T with a surface coil. Subjects took part in two main scanning sessions, each consisting of 5 correlated and 5 anticorrelated scans. The stimulus was a random-dot circular patch in which the disparity was changed from positive to negative in one quadrant every second (the 'active' quadrant). After 4 s, the next quadrant became active. The change in BOLD signal was measured in V1, V2, V3, V3A, hV4, V7, and MT+ for both conditions. All subjects showed activation to both stimulus types. The magnitude of the BOLD response was not significantly different in any single area, although overall it was significantly lower for anticorrelated stimuli. However, in all visual areas, the reliability of the response (measured as correlated with stimulus change) was significantly higher for binocular correlation than anticorrelation (paired t -test; $p < 0.05$). Although there is a widespread cortical response to anticorrelated stimuli, it appears more variable than for correlated stimuli.

[Supported by the Royal Society, and the Medical Research Council.]

◆ **Percept choices at the onset of ambiguous or binocular rivalry stimuli**

R J A van Wezel, A J Noest¶, M M Nijs, R van Ee§ (Helmholtz Institute [¶ Department of Functional Neurobiology], Utrecht University, Padualaan 8 [§ Princetonplein 5], NL 3584 CH Utrecht, The Netherlands; e-mail: r.j.a.vanwezel@bio.uu.nl)

We studied the percept chosen by the visual system at the onset of ambiguous or binocular-rivalry stimuli. We used two different stimuli: a monocularly viewed ambiguous rotating sphere and a binocular-rivalry stimulus. These stimuli evoke primarily two different percepts. The ambiguous sphere evokes clockwise or anticlockwise rotation and the binocular-rivalry stimulus switches from one eye to the other. The stimuli were presented intermittently for a specific combination of stimulus-on time (T -on, ranging between 0.7 and 2.0 s) and a time where the stimulus was off (T -off, ranging between 0.1 and 4.0 s). Subjects were instructed to indicate which of the two percepts was dominant at the onset of the T -on phase. Our results show that at short T -off periods the percept alternates, while at long T -off periods the previous percept is chosen.

Monday

The transition in the T -off time where the percepts change from alternation to repetition is independent of T -on and about 8 times shorter than the average switch duration during continuous presentation of the same stimuli. We also investigated the influence of attention on repetition and alternation percepts. We show that a simple single-stage model of competing neural representations can account for the results.

[Supported by the High Potential Programme, Utrecht University.]

◆ **Monocular versus binocular perception of mirror anamorphoses**

K Brecher (Departments of Astronomy and Physics, Boston University, 725 Commonwealth Avenue, Boston, MA 02215, USA; e-mail: brecher@bu.edu)

Although artists have produced mirror anamorphoses for nearly four centuries, little has been written about their appearance when viewed monocularly versus binocularly. Cylindrical anamorphoses provide conflicting visual signals for the location of the observed image. At typical viewing distances of 30–60 cm for cylinder mirrors of diameter 3–6 cm, each eye is presented with a different image. The depth cues from binocular disparity, convergence, and accommodation are inconsistent with the object location deduced from the monocular cues in the virtual mirror image. Direct comparisons between real objects and reflected images of anamorphed photographs of the same objects at the same physical scale make these differences apparent. Both three-dimensional objects and two-dimensional pictures have been used to examine the differences between monocular, binocular, and synoptic (the same image presented to both eyes) viewing of their reflected anamorphed images. Preliminary studies suggest that monocular and synoptic viewing of anamorphoses elicit more ‘realistic’ percepts of the source objects than does binocular viewing. Experiments comparing the appearances of real objects with their anamorphed images viewed on curved surfaces offer a novel way to explore the relative weight placed by the human visual system on the various depth cues.

[Supported by US NSF grant # DUE-0125992.]

◆ **Minimum depth discrimination in a stereoscopic display with a depth-fused 3-D effect**

H Kuribayashi, Y Ishigure¶, H Takada¶, M Date¶, S Suyama¶, K Ishikawa, T Hatada (Department of Media and Image Technology, Tokyo Polytechnic University, 1583 Iiyama, Atsugi-shi, Kanagawa 243-0297, Japan; ¶ NTT Cyber Space Laboratories, NTT Corporation, 3-9-11, Midori-Cho, Musashino-Shi, Tokyo 180-8585, Japan; e-mail: hide-kuri@nifty.com)

The depth resolution of an ordinary stereoscopic display depends on the pixel pitch of the display. Because electronic displays usually have discrete pixels, it is impossible to achieve fine binocular disparity of less than 1 pixel. To overcome this problem, we proposed a new method consisting of adding narrow side-edge zones, like the retinal images of DFD displays (depth-fused 3-D) and modulating their luminance. The term DFD displays is used when an apparent 3-D image in the display can be perceived from only two 2-D images displayed at different depths when an observer views them from the direction in which they overlap. We verified that the perceived depth was proportional to the luminance of the edge zones Kuribayashi et al, 2005 *Proceedings of the EuroDisplay 2005 Conference, Edinburgh, Scotland (USA: SID)* pp 31–34]. Here, we report our experimental investigation of the minimum depth discrimination in this display method. We found that, when the edge width is narrow enough, the observer can perceive finer depth than is possible with the usual stereoscopic display method. The minimum depth discrimination is almost the same as the human sensitivity of binocular disparity detection. Therefore, we believe this new method can present more continuous depth than an ordinary stereoscopic display.

◆ **Multiple slant-rivalry stimuli alternate independently**

T Knapen, M Struiksma, R van Ee (Helmholtz Institute, Utrecht University, Princetonplein 5, NL 3584 CC Utrecht, The Netherlands; e-mail: t.h.j.knapen@phys.uu.nl)

Two simultaneously presented bistable stimuli such as Necker cubes can produce four different percepts. The nature of the relationship between these percepts enables us to examine whether perception is determined by low-level signals constituting depth or by high-level object-based interpretations. To investigate this systematically, we used two slant-rivalry stimuli, one surrounding the other. In a single slant-rivalry stimulus, subjects experience one of two opposite surface slants: one based on perspective foreshortening, the other based on binocular disparity. The percepts of two slant-rivalry stimuli may be independent, but they may also be based on (dis)similarity of signals (disparity and perspective), or the resulting slant. We demonstrate that all four possible percepts occurred frequently, indicating that multiple slant-rivalry planes alternate quite independently. When compared to slant rivalry with a frontoparallel surround, there was a significant change in alternation rate of the inner plane only when both planes were bistable.

Duration ratios of perspective-dominated and disparity-dominated percepts showed a significant effect dependent on the disparity slant of the outside plane. The interactions between slant-rivalry stimuli are based on the cues involved and do not constrain the array of possible percepts, resulting in independent rivalry of the two planes.

- ◆ **Fusional limit of distance between front and rear images in the depth-fused 3-D visual illusion**
H Takada, S Suyama, M Date, Y Gotoh¶ (NTT Cyber Space Laboratories, Nippon Telegraph and Telephone Corporation, 3-9-11, Midori-Cho, Musashino-Shi, Tokyo 180-8585, Japan;
¶ Academic Center for Computing and Media Studies, Kyoto University, Yoshida-Honmachi, Sakyo-ku, Kyoto 606-8501, Japan; e-mail: takada.hideaki@lab.ntt.co.jp)

The depth-fused 3-D (DFD) visual illusion consists of two processes. First, two images with the same shape displayed at the front and rear frontoparallel planes are perceived as a single image at one depth. Second, we can perceive a continuous depth change when the luminance ratio between the front and rear images is continuously changed according to the 3-D image depth. However, the effective range of distance between the front and rear images has not been determined. Using subjective tests, we evaluated how the fusion of the DFD visual illusion depended on the distance between the two images when this distance was changed, and we examined the influence of the fusional limit of depth when the observation distance was changed. As a result, we clarified the fusional limit of depth in the DFD visual illusion. We found that the front and rear images could fuse at a distance of about 3 min of arc or less between the two images. Moreover, we found that the fusional limit did not change when the observation distance was changed. Thus, our DFD visual illusion can be perceived only when the distance is small.

- ◆ **Retinal correspondence and the theoretical horopter**
K M Schreiber, C M Schor (School of Optometry, University of California at Berkeley, 360 Minor Hall, Berkeley, CA 94720, USA; e-mail: kai@berkeley.edu)

Disparity is usually considered a 2-D vector representing deviation from retinal correspondence, and visualised as the theoretical horopter, the set of locations projecting onto correspondence pairs. Disparity is assumed to decompose naturally into two orthogonal components, horizontal and vertical disparity, processed in fundamentally different ways by the visual system. But when eye movements and non-identical correspondence patterns are taken into account, simple definitions of retinal disparity break down. In general, horizontal and vertical disparity and the disparity vector itself are not well-defined entities. Retinally, a binocular target is represented by one 2-D position vector per eye—four dimensions. If disparity is assumed to be the difference between these projection vectors and a retinal correspondence pattern, the resulting entity has eight degrees of freedom—four more than a retinal disparity vector. Only when empirical correspondence obeys certain constraints is disparity reducible to such a vector. But even then it cannot be simply split into retinal horizontal and vertical components, as eye movements change epipolar projection geometry. We present an extension of the concept of the theoretical horopter that takes into account these issues and demonstrates a practical consequence with the induced effect as an example.

[Supported by Emmy-Noether-Programm der Deutschen Forschungsgemeinschaft, NIH-NEI]

- ◆ **Binocular rivalry, binocular transparency, and layer 4C in V1 as neural substrate for phenomenal visual consciousness**
C Q Wu (Perception and Cognition Research Institute, Shanghai 201203, China; e-mail: charlesqwu@percog.org)

When an observer's two eyes receive disparate stimulation, three possibilities may occur in the observer's visual consciousness: binocular rivalry, binocular transparency, and binocular composition. Here I demonstrate that the site of consciousness suppression in binocular rivalry must be monocular. I further suggest that binocular transparency is the maintenance in visual consciousness of two monocular images at different depth planes and that binocular composition is a special case of binocular transparency where the two monocular images are maintained at the same depth plane. In this view, binocular rivalry, binocular transparency, and binocular composition constitute a continuum of all possible percepts under dichoptic stimulation; in normal binocular viewing, for any depth plane either one monocular image or two monocular images (as in binocular composition) are represented in visual consciousness. Mapping onto the organisation of the human visual system, I suggest that the principal thalamic recipient layer 4C in the primary visual cortex (V1) is the neural substrate for phenomenal visual consciousness and is layer-structured where visual surfaces are represented. Layer 4C has traditionally been viewed as the first stage of cortical visual processing, but I contend that this layer is the final stage of cortical computation for each and every episode of visual consciousness.

Monday

◆ Exploring the parameter space of stimulus rivalry

J J A van Boxtel, T Knapen, R van Ee, C J Erkelens (Department Physics of Man, Helmholtz Institute, Utrecht University, PO Box 80 000, NL 3508 TA Utrecht, The Netherlands; e-mail: j.j.a.vanboxtel@phys.uu.nl)

A central question in the investigation of binocular rivalry is what is actually rivaling during binocular rivalry. Two main possibilities have been suggested: eye rivalry, and stimulus rivalry. Logothetis et al (1996 *Nature* **380** 621–624) have shown that seemingly normal rivalry occurs when the stimuli are swapped between the eyes (when eye rivalry cannot take place), indicating that stimulus rivalry exists. However, Lee and Blake (1999 *Vision Research* **39** 1447–1454) have shown that stimulus rivalry occurs only in a relatively small parameter space. In our experiments the stimuli of both eyes were shown simultaneously for n frames, followed by m blank frames, after which they were swapped between the eyes. We independently varied the temporal duty cycle $[n/(n+m)]$, and the swapping period $(2n+2m)$. Stimulus rivalry can be instigated when swapping periods are less than ~ 600 ms and duty cycle is larger than 0.25 but not 1. This was found even though the spatial frequency (2 cycles deg^{-1}) was outside of the range in which previous studies reported stimulus rivalry. Additional analysis suggests that the blank time before swapping the images between the eyes is an important parameter in determining whether stimulus rivalry does occur.

◆ Testing a counterintuitive prediction of optimal cue combination

C M P Muller, E Brenner, J B J Smeets (Faculty of Human Movement Sciences, Vrije Universiteit, Van der Boechorststraat 9, NL 1081 BT Amsterdam, The Netherlands; c.m.p.muller@fbw.vu.nl)

When visual scientists talk about cues being combined in an optimal manner what they generally mean is that they are combined in the way that gives the least variability in the resulting estimate. For independent cues for the same attribute this is achieved by weighted averaging, whereby the weights only depend on the reliability of the separate cues. Consequently, the weights assigned to the cues should be completely independent of whether the cues indicate exactly the same value or are clearly in conflict, and the variability in the final estimate should be independent of the consistency between the cues. We tested the latter, somewhat counter-intuitive, prediction by comparing the reproducibility in matching the slant of a reference surface when monocular and binocular cues indicated the same slant, with the reproducibility when the cues indicated slants that differed by 15° . In accordance with the counter-intuitive prediction, the variance in the matches was no larger when the cues were in conflict. This cannot be so when the conflict is so large that the cues are no longer combined by weighted averaging, but the fact that it holds for a substantial difference provides strong support for optimal cue combination in the human visual system.

◆ Depth aftereffects influence detection thresholds of concave or convex surface deformation

C Devisme, B Drobe¶, A Monot§, G Giraudet¶, J Droulez# (LPPA–Collège de France CNRS, 11 place Marcellin Berthelot, F 75005 Paris, France; ¶ Essilor International, R&D Optics, Vision Science, 57 avenue de Condé, F 94106 Saint-Maur, France; § MNHN, CRCDG–Équipe Vision, 36 rue Geoffroy-Saint-Hilaire, F 75005 Paris, France; e-mail: devismec@essilor.fr)

Perceptual depth adaptation can produce a depth aftereffect, or successive contrast effect: after 8 s adaptation with sinusoidal depth corrugations, a flat surface appeared corrugated in depth with opposite phase (Graham and Rogers, 1982 *Perception* **11** 247–262). We wished to find out whether aftereffects generated by surfaces with continuously varying disparity can modify detection thresholds of these surfaces. A surface deformation detection task was performed with an ascending adjustment procedure: stimuli were cyclopean images (Devisme et al, 2005 *Perception* **34** Supplement, 114). A concentric horizontal disparity gradient, crossed or uncrossed, was progressively increased, starting from null disparity, between two eccentricities. Five observers were asked to indicate when they perceived a concave or convex deformation of the frontoparallel surface. A depth aftereffect was reported on the first subsequently presented image. Comparison was made between deformation detection thresholds relative to the depth aftereffect direction: identical or opposite to the present surface deformation. Results showed a significant sensitivity to aftereffect, for crossed and uncrossed disparities. Depth aftereffect, perceived or not, can improve the detection of concave or convex surface deformations when they are in the same direction, or impair them when they are in the opposite direction.

◆ **Familiar form and motion influence perceptual dominance**

L Chuang, Q C Vuong, I M Thornton, H H Bülthoff (Department of Cognitive and Computational Psychophysics, Max Planck Institute for Biological Cybernetics,

Spemannstrasse 38, D 72076 Tübingen, Germany; e-mail: lewis.chuang@tuebingen.mpg.de)

Binocular rivalry can occur when two different stimuli are presented separately to each eye. Typically, the dominant percept alternates between the two presented stimuli. Prior studies have shown that perceptual dominance can be induced by low-level factors such as luminance as well as high-level factors such as object categories, suggesting that rivalry reflects competition at multiple levels of visual processing. Here, we investigated whether learned shape and motion of rigidly rotating objects can bias perceptual dominance during binocular rivalry. Observers first learned four novel objects that each rotated in a specific direction. These objects were randomly created by free-form deformation techniques. Following learning, we induced binocular rivalry between a learned object and a novel distractor. The learned object could rotate in its learned or reversed direction. For comparison purposes, we also included pairs of only novel objects. Initial results show that learned objects rotating in their learned direction are perceptually dominant more often than the paired distractors. Learned objects rotating in reverse do not appear to differ from novel objects in terms of perceived dominance. These findings suggest that binocular rivalry could provide a useful implicit measure of the roles played by shape and motion during object recognition.

1-D, 2-D, 3-D SHAPE, SCENE, SPACE

◆ **Dividing attention between shape and depth**

M Grosjean, G Rinkenauer (Institute for Occupational Physiology, University of Dortmund, Ardeystrasse 67, D 44139 Dortmund, Germany; e-mail: grosjean@ifado.de)

When attention is divided across locations in 2-D space, responses to redundant targets are generally faster than responses to single targets. The goal of the current study was to establish whether such redundancy gains, as they are known, also arise when redundant targets are (i) defined by shape-alone information presented in different depth planes, and (ii) defined by shape and depth information. In the first experiment, participants were asked to respond to the presence of one and/or two target stimuli that were stereoscopically presented at a near-depth plane, a far-depth plane, or distributed across the two depth planes. Redundancy gains were obtained for all depth conditions and the size of the effects did not vary as a function of the stimuli appearing in the same or different depth planes. This suggests that attention can be effectively divided across locations in 3-D space. In the second experiment, participants responded to the appearance of a single target stimulus that had the correct shape and/or depth. Evidence for an advantage of redundant targets (ie with the proper shape and depth) was again obtained, which shows that attention can also be divided between shape and depth information.

◆ **The effect of category learning on the representation of separable shape dimensions: Aspect ratio and curvature**

B Ons, J Wagemans, H P Op de Beeck (Laboratory of Experimental Psychology, University of Leuven, Tiensestraat 102, B 3000 Leuven, Belgium [also ¶ McGovern Institute for Brain Research, Massachusetts Institute of Technology, 77 Massachusetts Avenue, Cambridge, MA 02139, USA]; e-mail: bart.ons@psy.kuleuven.be)

Most models of categorisation describe categorisation in two steps. First, a distance between an object and a category is extracted from a psychological similarity space. Secondly, computations on these distances determine the probability of assigning a new object to a category. In these models, categorisation depends on the similarity between stimulus representations. This study examines the reverse influence of categorisation on the representation of stimuli. New, artificial 2-D shapes (which looked a bit like chromosomes) were created by combining two separable shape dimensions: aspect ratio and curvature. In the first experiment, subjects completed a categorisation task of one hour, based on a one-dimensional criterion (eg curvature as relevant) and ignoring the variability on the second dimension (eg aspect ratio as irrelevant). A subsequent same-different task showed improved discriminability for the relevant shape dimension (eg d' increase from 2 to 3). Additional experiments will investigate how this learning effect for aspect ratio or curvature generalises towards other stimulus sets and how a 45° rotation for the relevant and the irrelevant dimension in the same stimulus space (making the dimensions integral instead of separable) will affect this learning effect.

[Supported by grants IDO/02/004 and FWO G.0281.06.]

Monday

◆ **The coding of 3-D shape from shading in macaque areas TE and TEO**

J Vangeneugden, K Koteles¶, G A Orban, R Vogels (Department of Neuro- and Psychophysiology, University of Leuven Medical School, 49 Herestraat, B 3000 Leuven, Belgium; ¶Department of Physiology, Medical University, 10 Dom Ter, H 6720 Szeged, Hungary; joris.vangeneugden@med.kuleuven.be)

Previous studies demonstrated that neurons in the ventral part of the rostral superior temporal sulcus, part of the inferior temporal (IT) cortex, respond selectively to 3-D shape defined by binocular disparity (Janssen et al, 1999 *Proceedings of the National Academy of Sciences of the USA* **96** 8217–8222; 2000 *Science* **288** 2054–2056) and for depth defined by texture gradients (Liu et al, 2004 *Journal of Neuroscience* **24** 3795–3800). We investigated (i) how IT neurons (area TE and TEO) encode 3-D shapes defined by shading (another monocular depth cue) and (ii) whether the response to the shaded objects is affected by direction of illumination. The stimuli consisted of 3-D shapes defined by shading, 2-D control shapes with and without the same overall luminance gradients and pixel-scrambled controls. The stimuli were presented foveally during single-unit recordings in two awake, fixating rhesus monkeys from either area TE or area TEO. Our results showed that (i) the responses to the stimuli clustered very well in a low (three-)dimensional space; (ii) there was a similar selectivity between the 3-D and 2-D shapes; (iii) there was no effect of direction of illumination; and, finally, (iv) neurons in area TEO responded more to 3-D shapes defined by shading vs 2-D shapes with (two monkeys) and without (one monkey) the same overall luminance gradients. Thus, TEO neurons seem to encode 3-D shape defined by shading.

◆ **Generalised morphological 3-D shape decomposition gray-scale interframe interpolation method**

D N Vizireanu (Faculty of Electronics, Telecommunications and Informations Technology, Polytechnic University of Bucharest, blvd Iuliu Maniu 1–3, RO 060032 Bucharest, Romania; e-mail: nae@comm.pub.ro)

One of the main image representations in mathematical morphology is the 3-D shape decomposition representation, useful for image compression and representation, and pattern recognition. The 3-D morphological shape decomposition (MSD) representation can be generalised a number of times, to extend the scope of its algebraic characteristics as much as possible. With these generalisations, the role of MSD as an efficient image decomposition tool is extended to gray-scale images. This work follows the above line, and further develops it. A new evolutionary branch is added to the development of 3-D MSD, by the introduction of a 3-D multistructuring element MSD, which permits addition of 3-D MSD of 3-D binary images (gray-scale images) to 'multi-parameter' families of elements. At the beginning, 3-D MSD representations are based only on 'one-parameter' families of elements for image decomposition. This paper addresses the gray-scale interframe interpolation by means of mathematical morphology. The new interframe interpolation method is based on generalised morphological 3-D shape decomposition. I present the theoretical background of the morphological interframe interpolation, deduce the new representation, and show some application examples. Computer simulations are used to illustrate the results.

◆ **Global shape coherence: Probing the mechanisms underlying shape detection**

D M Bennett, G E Gordon, G N Dutton¶, G Löffler (Department of Vision Sciences, Glasgow Caledonian University, 70 Cowcaddens Road, Glasgow G4 0BA, Scotland, UK; ¶Department of Paediatric Ophthalmology, Royal Hospital for Sick Children, Glasgow, Scotland, UK; e-mail: david.bennett@gcal.ac.uk)

The proportion of coherent signal elements required to detect a global signal is a standard tool for investigating motion perception. This paradigm was applied to the shape domain to examine how global shape-detectors pool local orientation information. Stimulus arrays consisted of oriented Gabors (totalling 150) that sampled the circumference of concentric shapes in a polar grid. Individual Gabors were oriented tangentially to the global shape (signal) or randomly (noise); coherence was the independent variable. Different shapes (modulated circles) were tested by varying lobe number (0 = circle, 2 = ellipse, 3 = triangle-shaped, 4 = square-shaped, 5 = pentagon-shaped, 8 = octagon-shaped) and modulation amplitude ('sharpness' of the lobes). In experiment 1, signal elements were located randomly within the array; in experiment 2, they were positioned within selected annuli. Detection threshold (approximately 15 coherent elements = 10%) was unaffected by the shape (up to 4–5 lobes). Confining the signal to one annulus greatly reduced the number of elements needed to reach threshold (between 4–6). Thresholds deteriorated when the number of lobes was increased further and rose dramatically when amplitudes increased. Results are consistent with the existence of highly sensitive, shape-specific global analysers that sum information within annuli. Overall performance for arrays of local elements can be explained by the summation of multiple concentric shape-detectors.

[Supported in part by EPSRC Grant No. GR/S59239/01.]

◆ **The light-from-above prior in visual search and shape judgments**

W J Adams (School of Psychology, University of Southampton, Shackleton Building, Highfield, Southampton SO17 1BJ, UK; e-mail: w.adams@soton.ac.uk)

The 'light-from-above' prior is invoked to simplify and expedite complex visual processing. This prior is observed in visual search and shape judgments with shape-from-shading (SFS) stimuli: Disks with vertical shading gradients are more efficiently discriminated from 180° rotated stimuli than when target and distractors have horizontal shading gradients. In shape judgments, shaded disks that are brightest at the top appear convex and those brightest at the bottom appear concave, consistent with light from above. Disks with horizontal gradients have reduced, more ambiguous apparent depth. Do the light-from-above priors exhibited by different tasks have the same underlying mechanism, or even direction? Some evidence has suggested that an 'above-left' rather than 'above' prior guides behaviour in some tasks, but not others. In the current study, the 'light-from-above' prior was measured by using both visual search and shape judgments. There were substantial differences between observers. However, a very strong positive correlation between the light prior measured with the use of the two tasks suggests a common mechanism for the 'quick and dirty' visual-search task and shape perception. Furthermore, the data imply that perceived shape is the pre-attentive feature in visual search with SFS targets, rather than perceived luminance or shading orientation per se.

[Supported by EPSRC (EP/D039916/1)]

◆ **The influence of categorisation on perceived shape similarity within natural object categories**

C R Gillebert, H P Op de Beeck[¶], B Ons, J Wagemans (Laboratory of Experimental Psychology, University of Leuven, Tiensestraat 102, B 3000 Leuven, Belgium;

[¶]also McGovern Institute for Brain Research, Massachusetts Institute of Technology, Cambridge, MA 02139, USA; e-mail: celine.gillebert@student.kuleuven.be)

Previous studies have found effects of categorisation on perceived shape similarity with artificial shapes. Here we ask to what extent similar effects are present with objects from natural categories. We trained sixteen subjects on a perceptual categorisation task (PCT). For each of four categories (birds, cars, fishes, and vases), we started from four extremes in a measured two-dimensional similarity space and created horizontal and vertical morph lines between them. Each subject learned to categorise two of these shape-spaces according to a vertical or horizontal categorisation rule. During the last training session, performance was gradually worse for stimuli closer to the category border. To control for an effect of familiarity, subjects also viewed stimuli of a third category in an odd man out task (OMOT). After training, subjects performed a same-different task on all three categories. We found a general effect of categorisation on perceptual discrimination (compared to categories after OMOT only), but no effect of the relevance of the dimension. Results did suggest a clustering effect: the perceived difference was considerably larger for stimuli that crossed the category boundary compared to stimuli that belonged to the same category. Thus, category training altered perceived shape similarity within natural object categories. [Supported by IDO/02/004 and FWO G.0281.06.]

◆ **Repetition priming in 3-D form and motion recognition**

P Sarkheil, Q C Vuong, H H Bülthoff, U Noppeney (Department of Cognitive and Computational Psychophysics, Max Planck Institute for Biological Cybernetics,

Spemannstrasse 38, D 72076 Tübingen, Germany; e-mail: pegah.sarkheil@tuebingen.mpg.de)

Behavioural studies have highlighted the importance of dynamic information for object recognition: Object motion provides additional views and image features that may facilitate the extraction of 3-D shape. However, even the direction of in-depth rotation that controls for shape and view information affects recognition performance. Here, we used a priming paradigm to investigate the effects of motion direction and form as well as their interaction during dynamic object recognition. Furthermore, two task-contexts were used to investigate the effects of top-down modulation on behavioural priming effects. For these contexts, subjects responded on the basis of object form or motion. Subjects were presented with pairs of successive objects rotating in depth. They performed a two-alternative forced choice form or motion categorisation to the second object. The conditions conformed to a $2 \times 2 \times 2$ factorial design manipulating (i) object form (same/different pairs), (ii) in-depth rotation (same/different pairs), and (iii) task (motion/form). We observed that form and motion priming effects interacted and were enhanced in congruent task context. These findings suggest that dynamic 3-D object recognition is accomplished through interaction of form and motion information. Furthermore, both form and motion priming are influenced by task requirements. Future fMRI studies will investigate these effects at the neuronal level.

[Supported by the Max Planck Institute.]

Monday

◆ Contextual relativity of 3-D object representations

H Brettel, M Gschwind[¶], I Rentschler[¶] (Department TSI, École Nationale Supérieure des Télécommunications, CNRS UMR 5141, 46 rue Barrault, F 75013 Paris, France; [¶] Institute of Medical Psychology, University of Munich, Goethestrasse 31, D 80336 Munich, Germany; e-mail: brettel@enst.fr)

Recently, we showed that context affects the nature of 2-D pattern representations constructed through category learning (Jüttner et al, 2004 *Visual Cognition* **11** 921–945). Here we use a similar approach to address the problem of 3-D object recognition. Within a paradigm of supervised category learning and generalisation to novel views, we used computer graphic images of 3-D objects of varying degree of structural regularity and connectivity of parts. Our results suggest that image information and contextual knowledge affect object recognition in three steps. First, image understanding is achieved by generating internalised 3-D models from input data. Such solutions of ‘inverse problems’ depend both on image information and contextual knowledge observers may have about test objects. Second, the resulting candidate 3-D models are disambiguated with regard to their membership in object categories. The latter task poses a classification problem, the solution of which depends on the distinctness of class descriptions. Third, these steps are not unique but occur within an iterative process that aims at minimising misclassification. Taken together, our results suggest that visual 3-D object recognition is view-dependent or view-invariant depending on what stimulus information is available and what observers know about test objects.

◆ Effect of contrast on motion surface labeling in 3-D structure-from-motion

T Yoshizawa, T Kawahara, D Nakayama (Human Information System Laboratory, Kanazawa Institute of Technology, 3-1 Yatsukaho, Hakusan, Ishikawa 924-0838, Japan; e-mail: tyoshi@his.kanazawa-it.ac.jp)

It has been reported that perceived reversals of rotation direction of a simulated cylinder are due to ambiguity of the interpretation which motion surfaces is in front of another. To investigate what kind of factors can give a solution to define 3-D structure, we tested here the effect of contrast of dots against a background on motion surface labeling. We simulated a transparent rotating cylinder. The simulated surface of the cylinder was covered by 80 dots whose luminance was either varied in a sinusoidal manner in the range of $6.3 - 71.5 \text{ cd m}^{-2}$ or fixed at 0 cd m^{-2} . The cylinder was presented on a background at either 77.8 cd m^{-2} (W condition) or 0.0 cd m^{-2} (B condition). When the luminance was fixed, most observers perceived both directions of the rotating cylinder with an equal probability. However, the dominant perceived direction of the cylinder depended on the background condition when the luminance of the dots was varied. That is, the perceived direction under W condition is opposite to that under B condition. This indicates that contrast against the background has an important role in providing depth information to define 3-D structure of the cylinder. [Supported in part by a Japanese MEXT grant 17530537 to TY.]

◆ Investigation of autocorrelation coefficients of 3-D object shells

O I Krasilnikova, N N Krasilnikov (Department of Information and Network Technologies, State University of Aerospace Instrumentation, Bolshaya Morskaya 67, 190000 St Petersburg, Russia; e-mail: nnkk23@aanet.ru)

We investigated experimentally how the autocorrelation coefficient of 3-D object shells depends on the angles determining the aspect of the object. In our experiments we used 3-D images of various complexity, from geometrical primitives to human faces and figures that were generated by means of 3-D graphic editors. For 3-D objects with complicated shape, the measurement of root-mean-square distance between shells of original and turned 3-D objects is a difficult problem. Therefore we developed an approximate method based on 3-D object presentation with a set of contours produced by their sections by a series of parallel planes. We showed that, in the general case, the autocorrelation coefficient of 3-D object shells depends non-exponentially on the angle which determines the aspect; in this case the autocorrelation coefficient of 3-D object shells does not depend upon object sizes. In the case of complex objects, a function relating the autocorrelation coefficient and the aspect angle can have some peak values. The obtained results can be used in systems intended for digital stream compression when 3-D scenes are transmitted and, particularly, in virtual-reality systems.

◆ Perspectives of virtual reality research in Kazakhstan

T Mukhithidnova, N Khon, N P Foreman[¶], A Kim, S Dzhaupov (Department of Psychology, al-Farabi Kazakh National University, 71 al-Farabi Avenue, Almaty 050078, Kazakhstan; [¶] School of Health and Social Sciences, Middlesex University, Queensway, Enfield EN3 4SF, UK; e-mail: tansulu@rambler.ru)

Virtual reality (VR) research in Kazakhstan started in 2005 with the launching of the first Kazakhstani PhD program in psychology. The influence of age, gender and activity/passivity on

spatial cognition, as well as effects of memory, attention, and stress in spatial navigation have been examined. Comparative analysis of cognitive processing in real and virtual environments is the overall aim of our research. Previous international research has documented significant gender differences for some spatial tasks, including specific computer-generated tasks, favouring males (Astur et al, 1998 *Behavioural Brain Research* **93** 185–190). However, it does not seem that this is the case for all aspects of spatial performance. In some VR studies which allowed longer exposure to virtual environments female subjects improved significantly over time. VR studies of the influence of active versus passive spatial experience on acquisition and transfer of spatial knowledge also report varied findings (Wilson and Péruch, 2002 *Current Psychology of Cognition* **21** 601–633) which may depend on environment, task difficulty, and interface familiarity.

◆ **Perceptual tests for 3-D pseudo-holographic displays**

G J Brelstaff, E Gobetti, G Zanetti (Visual Computing Group, CRS4, Polaris, Edificio 1, CP 25, I 09010 Pula, Italy; e-mail: gjb@crs4.it)

How best can new 3-D pseudo-holographic displays be evaluated? Criteria established for 2-D monitors and earlier autostereoscopic devices, although valid, provide little or no indication of the immediacy and responsiveness of the stereoscopic and motion-parallax cues available to the observer—free to move both head and body—in front of the display, such as Holografika's large-screen, computer-controlled, multi-projector video system (developed under the EU Project COHERENT-IST-FP6-510166). Here we present two perceptual tests designed to complement the large set of electro-optical evaluation/calibration tests also being applied to the device. The first test invokes variants of Julesz's spiral-staircase random-dot stereogram to demonstrate that even under adverse conditions binocular fusion is rapid. The second test reverses the logic of the Pulfrich pendulum illusion to assess motion-in-depth cues—avoiding various technological pitfalls. By darkening a variable-density filter worn over one eye, the observer is asked to annul the motion-in-depth of a the bob rendered by the display to follow a horizontal circular trajectory in depth. The screen is well calibrated if approximately the same darkening is required by the observer at all viewpoints in front of the screen. We report the design and initial results of both tests. [Supported by EU-IST-FP6-510166]

◆ **Asymmetry in the perception of motion in depth by moving cast shadows**

T Imura, N Shirai¶, M K Yamaguchi¶, M Tomonaga§, A Yagi# (Department of Psychology [§ Department of Integrated Psychological Science], Kwansei Gakuin University, 1-1-155 Uegahara, Nishinomiya, Hyogo 662-8501, Japan; ¶ Department of Psychology, Chuo University, 742-1 Higashinakano, Hachioji-shi, Tokyo 192-0393, Japan; § Section of Language and Intelligence, Primate Research Institute, Kyoto University, Inuyama, Aichi 484-8506, Japan; e-mail: imura@pri.kyoto-u.ac.jp)

Motion of the cast shadow provides effective information about object location (Kersten et al, 1996 *Nature* **379** 31). An object appears to approach when the cast shadow detaches from the object, and to recede when the cast shadow comes close to the object, although the object does not change in size and position. We examined the detection of approaching or receding objects defined by motion of a cast shadow using a visual-search task. Approaching motion is detected easier than receding motion in a visual-search task (Shirai and Yamaguchi, 2004 *Vision Research* **44** 1003–1011). In the present study, participants were asked to detect unique 'approaching' square among 'receding' squares (or vice versa). We found that an 'approaching' square was detected faster and more accurately than a 'receding' square. These results suggest that cast-shadow information contributes to rapid detection of a unique element in a visual search display, similarly to other pictorial depth cues (Kleffner and Ramachandran, 1992 *Perception & Psychophysics* **52** 18–36), and the human visual system might be biased to detect an approaching object.

◆ **Vergence eye movements based on monocular depth cues elicited by attention shifts between 2-D and 2½-D search layers**

M Wagner, W H Ehrenstein¶ (Smith Laboratory for Psychobiology, Hebrew University of Jerusalem and College of Judea and Samaria, IL 44837 Ariel, Israel; ¶ Leibniz Research Centre for Working Environment and Human Factors, University of Dortmund, Ardeystrasse 67, D 44139 Dortmund, Germany; e-mail: mwagner@cc.huji.ac.il)

We studied binocular vergence eye movements under conditions of attention shifts between 2-D and 2½-D search layers. Six normal-sighted subjects performed a feature search task within two superimposed layers, a 2-D frontoparallel and a 2½-D perspective display. Search items were gray-shaded features on a dark surface that were either plane or, in the perspective condition, volumetric and spatially arranged as if attached to a perspective depth surface grid with an elevated viewpoint (size following a depth gradient). By changing the form of the fixation sign,

Monday

preceding each trial, we pre-cued the respective target-layer location. Attention shifts between layers were elicited by manipulating valid and invalid target-layer location cues. Binocular eye movements were recorded with unrestrained head posture (EyeLink system); response times (RTs) for target detection were also taken. Vergence depended on attention shifts between layers: Shifts from 2-D to 2½-D elicited divergence, whereas convergence resulted from the reverse shift sequence. Single surface search required two saccades and RTs were independent of surface type or set size. Our results indicate that surface selection and segregation precede visual search of targets and that vergence eye movements can be controlled by monocular depth cues, ie by top-down (virtual depth) factors.

◆ **Induced motion-in-depth depends on eye movements**

H T Nefs, J M Harris (School of Psychology, University of St Andrews,

KY16 9JP St Andrews, Scotland, UK; e-mail: harold.nefs@st-andrews.ac.uk)

Illusory, induced, motion-in-depth is perceived in a physically stationary target when other targets move in depth in its vicinity (eg German and Harris, 2001 *Investigative Ophthalmology & Visual Science* 42 S617). The conventional hypothesis that changes in relative disparity and size are the dominant cues for perception of motion-in-depth predicts this effect. It also predicts that vergence movements are irrelevant. In order to test the latter hypothesis, we measured the point of subjective stationarity in a 2AFC task. Observers viewed an inducer target that oscillated in depth and a test target located directly above it. The test target moved in-phase or out-of-phase with the inducer, but with a smaller amplitude. Observers had to indicate the phase between target and inducer. They were asked to keep their eyes either on the test target or on the inducer. Eye movements were recorded throughout the experiment for both eyes. When the eyes were kept on the test target, stationarity occurred at about 10% of the inducer amplitude. When the eyes followed the inducer the bias increased five-fold to 40–55%. This is the first time that eye movements have been shown to have an effect on any type of induced motion-in-depth.

[Supported by the EPSRC and the University of St Andrews.]

◆ **Is the curvature of visual space isotropic?**

R Sikl, M Simecek (Institute of Psychology, Academy of Sciences of the Czech Republic,

Veveri 97, CZ 60200 Brno, Czech Republic; e-mail: sikl@psu.cas.cz)

It has been repeatedly shown that visual space is not of constant curvature. In this context, the effect of changing distance is typically mentioned, but this is surely not the only important spatial parameter determining the geometry of visual space. We addressed the effect of stimulus orientation in an exocentric pointing task. In the outdoor experiment, we used a novel technique of raising perpendiculars. Subjects—standing at the vertex of the reference square—indicated the point on the perimeter where the subjective line starting at a given point within the square intersects the square at a right angle. The experimental design had 72 conditions for 9 points within the square, 4 sides of the square and 2 scales (square sides equal to 4 or 10 m). The results revealed a systematic tendency to locate the answers more deeply in space for the exocentric-sides conditions. This tendency was observed more clearly in the larger square conditions and also when the angle between the observer's line of sight and the perpendicular was far away from 0° or 90° values. The results may indicate anisotropic curvature of visual space where the curvature in a given direction depends on the adjacency to frontal or radial dimensions.

◆ **Transsaccadic memory for the position of stationary and moving objects in a 3-D environment**

G G Van Belle, P De Graef, K Verfaillie (Laboratory of Experimental Psychology,

University of Leuven, Tiensestraat 102, B 3000 Leuven, Belgium;

e-mail: goedele.vanbelle@psy.kuleuven.be)

The intake of visual information occurs primarily during fixations interrupted by saccades. Previous experiments have shown that integration of object position across saccades is enhanced for translating objects, compared to stationary objects. Here, we investigated whether background motion influences this integration. For this purpose, a space-like 3-D environment was created with a background and a target ball. Background and target independently moved left or right with a constant speed, or remained stationary. After viewing this display for a certain time, participants had to make a saccade towards the target ball. During this saccade, the target could be displaced. We used a 2AFC procedure, in which two presentations with the same values for the independent variables immediately followed each other, one with and one without displacement. The subject then had to indicate in which of the presentations the displacement occurred. We compared the displacement detection for different background and target motion conditions. Results refine an earlier account of differences in the transsaccadic perception of the position of stationary versus moving objects in scenes.

◆ **Station-point violation and its consequences for size perception in simulated minimal-access surgery tasks**

J W Huber, I R Davies¶, N Stringer¶, A Hellmann§ (School of Human and Life Sciences, Roehampton University, Holybourne Avenue, London SW15 4JD, UK; ¶ Department of Psychology, University of Surrey, Guildford GU2 7XH, UK; § Institute of Psychology, Oldenburg University, D 26111 Oldenburg, Germany; e-mail: j.huber@roehampton.ac.uk)

In minimal-access surgery there are no recommendations from where surgeons view the monitor. The retinal image produced by viewing the monitor only replicates the 'natural' retinal image if viewed from a single point, the 'station-point'. If the image is used to control delicate movements, wrongly perceiving the layout could have serious consequences. In experiment 1, we assessed station-point violations by comparing shape judgments made at the correct station-point and half or double the station-point distance. Isosceles triangles of varying height to base ratios were viewed on a monitor. The surface with the triangles on was either normal to the camera or inclined at three different angles. The observer had to decide which triangle was equilateral. We found that accuracy of shape judgments declined as the angle of the surface increased, but station-point violation had no effect, implying that observers were compensating for station-point violation. In experiment 2, additional depth information was provided but the station-point still had no effect. Experiment 3 was performed to test the effect of violating the station-point through viewing the monitor obliquely. This time, accuracy for oblique viewing was worse than for normal viewing. For this condition, loss of accuracy is consistent with the optical changes resulting from station-point violations.

◆ **The early visual system's confounded discrimination of object property and viewpoint changes contributes to the viewpoint-dependence of object recognition**

M Demeyer, P Zaenen, J Wagemans (Laboratory of Experimental Psychology, University of Leuven, Tiensestraat 102, B 3000 Leuven, Belgium; e-mail: maarten.demeyer@psy.kuleuven.be)

Viewpoint-dependent recognition performance of 3-D objects has been taken as evidence for viewpoint-dependent object representations. We aimed to investigate whether these results can be explained by viewpoint and object property information not being detected independently (being correlated) at a lower level, prior to object recognition. We used a combination of multidimensional signal detection theory and perturbation analysis to test this idea. In study 1, we measured low-level correlations using a yes/no discrimination task. Subjects were instructed not to abstract viewpoint. We established that the correlations measured can be larger than those present in the input image, as computed with the aid of a pixel-based observer. In study 2, subjects had to categorise objects in a yes/no task while abstracting viewpoint. We found that the low-level correlations can only partially be overcome by object recognition: viewpoint dependence was linearly related to the low-level correlations with a slope of 0.66, significantly different from both 0 and 1. Task or stimulus differences are not responsible, since a pixel-based observer predicted a slope of 1. We conclude that low-level correlations prior to object recognition, both in the input image and the early visual system, can offer an explanation for viewpoint effects on the discrimination of 3-D objects.

[Supported by IDO/98/005, GOA/2005/03-TBA.]

◆ **Distortions of visual space in frontoparallel and sagittal layouts**

J A Aznar-Casanova, S Miguel, H Supér (Department of Basic Psychology, Faculty of Psychology, University of Barcelona, passeig de la Vall d'Hebron 171, E 08035 Barcelona, Spain; e-mail: jajnar2@ub.edu)

The size of an object appears to be constant with distance, while the retinal image of the object becomes smaller with distance. This illusion is explained by a hypothesis that puts forward a perceptual mechanism. According to this hypothesis, perceived size is the product of the size of the retinal image and the perceived distance. However, under certain conditions this description falls short of explaining size constancy. Here, we studied factors that contribute to depth perception. In the first experiment, we studied the visual angle of the stimulus, the orientation of the stimulus configuration, and the egocentric distance of the observer, and analysed their possible effects of on depth perception. The results show an influence of the visual angle and reveal an interaction with distance. In the second experiment, we studied the interaction between position of the stimulus (frontoparallel or sagittal) and the position of the observer (vertical or horizontal). The results show effects of under-constancy when both stimulus and observer have an orthogonal orientation and (over)constancy when the two are parallel.

Monday

◆ The geometry of visual space as a result of eye position shift

O Tosković (Department of Psychology, Faculty of Philosophy, Kosovska Mitrovica, Serbia; Laboratory for Experimental Psychology, Faculty of Philosophy, 11000 Belgrade, Serbia; e-mail: otoskovi@f.bg.ac.yu)

In previous research it was shown that physically shorter distances towards the zenith were seen as equal to physically longer distances towards the horizon. It remained unclear whether this difference in distance estimates is a consequence of a shift in the position of the body, of the head, or of the eyes. The aim here was to investigate whether the elliptical shape of perceived space is a consequence of an eye-position shift. The task of seventeen participants was to equalise the distances of three rectangular stimuli, in three directions (horizontal, tilted 12.7° , and tilted 24.26° relative to the horizon). Participants performed their estimates sitting on the floor, in a dark room, with their heads in a chin-rest, in order to prevent head and body movements. Results showed that (i) horizontal estimates were equal to standard, (ii) estimates in the 12.7° direction were shorter than the standard, and (iii) estimates in the 24.26° direction were longer than the standard. These results suggest that, as the eyes shift upwards, perceived space is elongated at first and then compressed, which conflicts with earlier results.

◆ The role of objectness in the detection of visual regularities

A Koning, N Kogo, J Wagemans (Laboratory of Experimental Psychology, University of Leuven, Tiensestraat 102, B 3000 Leuven, Belgium; e-mail: arno.koning@psy.kuleuven.be)

Regularities such as symmetry and repetition can facilitate visual object processing. Nevertheless, the interaction between type of regularity and objectness is not very clear. Previous research indicated that symmetric contours that appear to belong to one object may have an advantage over symmetric contours that appear to belong to two objects; and vice versa for repetition. However, both symmetry and repetition influence the perceptual grouping of elements in an image and therefore also the perceived number of objects (ie the objectness of visual elements). Here, we present three experiments in which projections of 3-D objects, as well as stereoscopically presented images, were used to more clearly separate one-object from two-object displays perceptually. In these experiments, participants had to indicate whether a regularity (symmetry or repetition, administered in separate blocks) was present or not. Overall, it was found that symmetry detection was easier for one-object displays than for two-object displays, and vice versa for repetition. More importantly, this result was found irrespective of the configuration of the presented elements. We conclude that this interaction between type of regularity and number of objects in fact depends on the objectness of the stimuli.

[Supported by the Research Council of the University of Leuven (F/04/075).]

PERCEPTUAL LEARNING

◆ Attentive visual search learning by practices

H Kojima (Department of Psychology, Kanazawa University, Kakuma, Kanazawa 920-1192, Japan; e-mail: hkojima@kenroku.kanazawa-u.ac.jp)

The 'pre-attentive' detection performance improved by an exercise (Ahissar and Hochstein, 1993 *Proceedings of the National Academy of Sciences of the USA* **90** 5718–5722). Here, I report that the 'attentive' search performance also improves with practice. The stimulus images consisted of several Gabor patches with spatial frequencies (SFs) of 1.25, 2.5, or 5.0 cycles deg^{-1} and a size of 0.6 deg of visual angle, and had four orientations: vertical, horizontal, 45° up, or 45° down. Visual search performances were recorded in four conditions over five consecutive days: (i) simple reaction time—to respond as quick as possible when any stimulus image was presented; (ii) simple discrimination task—to discriminate whether the presented patches were the same or different; (iii) simple search task—to judge whether there was a target characterised in one feature dimension, among others; (iv) combined search task—to judge whether there was a miscombined feature target among other distractors. The performances in the first three conditions improved only a little, approaching to an asymptotic base line over the days. The performance in the combined search condition improved dramatically after five days, indicating that the higher 'attentive' stage learned an efficient search process over the practices.

◆ Perceptual learning in roving conditions: Slow but specific

K Parkosadze, T U Otto¶, M Malania, A Kezeli, M H Herzog¶ (Laboratory of Vision Physiology, I. Beritashvili Institute of Physiology, Georgian Academy of Sciences, Gotua 14, Tbilisi 0160, Georgia; ¶ Laboratory of Psychophysics, Brain–Mind Institute, École Polytechnique Fédérale de Lausanne, CH 1015 Lausanne, Switzerland; e-mail: kparkosadze@yahoo.com)

In perceptual learning, no improvement of performance occurs when more than two stimulus alternatives are presented randomly interleaved during training (stimulus roving). For example,

if observers have to judge the position of a central line with respect to two outer lines (bisection task), improvement of performance is strongly impaired if the distance between the outer lines is randomly varied. However, we found that observers can improve performance in roving conditions if the training is very extensive (18000 trials per observer). Here, we show that long-term perceptual learning in roving conditions is still specific since we found no transfer to orthogonal line bisection stimuli. Moreover, roving seems to impede learning but not the performance of task, since thresholds in roving and non-roving conditions are comparable before and after training. Hence, improvement of performance cannot be attributed to an accommodation to the random order of stimulus presentation. Our results show that the specificities, typically found in perceptual learning, are preserved even if training extends over thousands of trials.

[Supported by Volkswagen Foundation and Swiss National Science Foundation.]

◆ **Invariant visual recognition in monkeys: Effect of the left prefrontal cortex lesion**

K N Dudkin, I V Chueva, F N Makarov (Pavlov Institute of Physiology, Russian Academy of Sciences, nab. Makarova 6, 199034 St Petersburg, Russia; e-mail: cognition@pavlov.infran.ru)

To understand a possible mechanism of hemispheric specialisation of the prefrontal cortex for invariant visual recognition, we studied learning processes involving visual discrimination of stimuli with different visual attributes on two groups of rhesus monkeys. The left prefrontal cortex sulcus principalis was removed in monkeys of the first group. The remaining intact animals served as control. The monkeys were tested for invariant recognition after complete training to visual discrimination and after stimulus transformations (variation in size, shape, orientation, and spatial relationships). Monkeys' correct decisions, refusals of making a decision, and motor reaction time were recorded. As compared with intact monkeys, after removal of left prefrontal cortex sulcus principalis learning processes became unstable for discrimination of all stimuli, and as a result the training periods were significantly lengthened. The transformation of stimuli involving geometrical figures of various shapes, sizes, and orientations did not influence correct decisions, though refusals of making a decision and the reaction time were increased. The invariance of this discrimination was achieved. However, the invariance for discrimination of stimuli connected with spatial information after transformation of spatial relationships was not achieved. These results indicate that left prefrontal sulcus principalis takes part in invariant visual recognition by forming demarcating features and providing spatial-information processing.

◆ **Learning to use informative features in shape categorisation**

T G Tanner (Department for Cognitive and Computational Psychophysics, Max Planck Institute for Biological Cybernetics, Spemannstrasse 38, D 72076 Tübingen, Germany; e-mail: tanner@tuebingen.mpg.de)

The aim of the study was to find out how humans learn to use informative features to categorise novel objects. Subjects were presented with a sequence of shapes, which they had to learn to classify into two categories. Immediate feedback about the true category was given after each trial. Stimuli consisted of large irregularly shaped contours containing several protrusions ('features'), whose curvatures varied stochastically from trial to trial. The exemplars for each class were drawn from partially overlapping Gaussian distributions in a multi-dimensional feature space. Thus, a single feature alone was often not sufficient to discriminate between classes and exemplars could be ambiguous. The features were independent and varied in diagnosticity (d') and perceptual discriminability. Importantly, the stimulus design made it possible to use eye-movement recordings to measure which features subjects looked at to perform the task. The results show that humans can learn to discriminate stochastic categories despite the inherent ambiguity of the task, and that with increasing expertise the fixations become more focused possibly reflecting the subject's belief about relevant features. The human data (performance, reaction times, and eye movements) are compared with an ideal observer and a variety of rational (Bayesian) learner models.

◆ **The role of response alternatives and stimulus duration**

E Tartaglia, G Tabin, T U Otto, M H Herzog (Laboratory of Psychophysics, Brain – Mind Institute, École Polytechnique Fédérale de Lausanne, CH 1015 Lausanne, Switzerland; e-mail: elisa.tartaglia@epfl.ch)

Strong improvement of performance in perceptual learning occurs when two stimulus alternatives have to be discriminated, whereas there is virtually no improvement if several alternatives are presented randomly interleaved (roving). It has been proposed that learning is not possible in roving conditions because of the absence of a stable reference template. Alternatively, it could be that performance cannot improve during training if the number of stimulus alternatives does not match the number of response alternatives, or if stimulus duration is too short. In a line-bisection task, subjects had to discriminate to which of two outer lines that delineate a spatial

Monday

interval, a middle marker was closer. In a first condition, two different outer line distances were presented randomly interleaved, and subjects had only two response alternatives given four stimulus alternatives. In a second condition, we offered four response alternatives for the four stimulus variants. In both conditions, we used two stimulus durations. While there is no learning in the first condition, preliminary results show an improvement in the performance for longer durations if stimulus alternatives match response alternatives..

VISION DECEIVED

◆ **Differential effects of the Judd illusion as a function of response modality: Hemispatial effects for pointing but not perceptual line matching**

A K Dunn, P Thompson (Division of Psychology, School of Social Sciences, Nottingham Trent University, Burton Street, Nottingham NG1 4BU, UK;
e-mail: andrew.dunn@ntu.ac.uk)

The Judd illusion is an illusion of perceived location: endpoint and unmarked midpoint positions are perceived to be shifted in a direction opposite to the direction of the arrow heads. We have previously shown (Dunn, 2003, unpublished PhD thesis, University of York, York, UK) that, contrary to expectations, both pointing and perceptual line-matching are affected by this illusion but that the pattern of effects are different across modality. One observed difference was an asymmetry in the magnitude of the pointing effect (not present in the matching data) depending upon target position relative to the participant's midline. Here, we explore two possible causes (hemispace vs biomechanical) by comparing left- and right-handed pointing for left- and right-handed individuals, to Judd targets in various locations either side of the midline. Our results demonstrate a hemispace advantage for ipsilateral dominant hand-targets (only) located just left or right of the midline. This is consistent with evidence in the literature and probably reflects a combination of spatial processing factors, including hemisphere specialisation for motor attention in the parietal lobe.

[Supported by BBSRC.]

◆ **The hollow-face illusion compared to inside-out hand illusions**

P F Heard, R Adams (School of Psychology, University of the West of England, Coldharbour Lane, Bristol BS16 1QY, UK; e-mail: priscilla.heard@uwe.ac.uk)

The hollow-face illusion occurs when a normal face is presented inside-out as a mould, but is seen as convex. Gregory explained this in terms of object knowledge winning over depth cues such as shadow and stereo. This illusion is less strong when presented upside down (Hill and Bruce, 1993 *Perception* **22** 887–897) which is evidence for object knowledge although the general rule of a convexity effect will also be operating. Another way to test the relative effects of object knowledge and convexity is to use familiar normally concave objects. When these are made inside out they are convex, so if they flip to look illusorily concave it cannot be due to a convexity effect. Ears have been described before (Heard and Chugg, 2003 *Perception* **32** Supplement, 50). We investigated plastic moulds of the palms and backs of left and right hands. Here, palms normally concave were convex, and backs of hands normally convex were concave, presented thumbs up or down. All versions of the inside-out hands gave strong illusions in that they flipped to look right-way-round. The effects of orientation and aspect of hand are described.

◆ **Illusion of curvature with contrast variations**

A-J Gutasukas, A Bertulis, A Bulatov (Department of Biology, Kaunas University of Medicine, Mickėvičiaus 7/9, LT 44307 Kaunas, Lithuania; e-mail: alggut@vision.kmu.lt)

We tested the influence of contrast changes of an equilateral triangle or square inscribed in a circle on the strength of the curvature illusion. The subjects adjusted the curvature of the arcs of the circle in order to reduce the illusion to zero, thereby producing a measure of the illusion strength. Stimuli 60 min of arc in diameter were presented on a background with a luminance of 7 cd m^{-2} . The luminance of the circle was fixed at 0 or 14 cd m^{-2} . The luminance of the inscribed figures varied from 0 to 20 cd m^{-2} in fifty steps. In the experiments, the illusion strength diminished when the luminance of the figure approached the background luminance value, and the figure was difficult to discern. The illusion strength increased with the figure luminance increase or decrease from the background luminance, saturating at higher contrasts. The illusion strength did not vary noticeably when the luminances of the inscribed figure and the circle were changing in parallel. The experimental data may be interpreted in terms of the spatial-frequency filtering concept (Bulatov and Bertulis, 2004 *Informatica* **15** 443–454).

◆ **A new optical-geometrical illusion**

D Bressanelli, M Massironi¶ (Department of General Psychology, University of Padua, via Venezia 8, I 35100 Padua, Italy; ¶ Department of Psychology and Cultural Anthropology, University of Verona, Lungadige Porta Vittoria 17, I 37129 Verona, Italy; e-mail: daniela.bressanelli@unipd.it)

Our aim is to describe and explain a new and unusual geometrical optical illusion with three levels of distortion. The illusory figure was made up of three juxtaposed bands of the same width—a parallelogram and two rectangular trapezoids—which, when appropriately juxtaposed, appeared to be of different widths. The illusion seems to share some aspects with other well-known illusions, such as Shepard's, Jastrow's, and Sander's. We hypothesised that the effect would depend on the combined action of the following factors: (i) global: the band shape, and 3-D perceptual assumption; (ii) local: the degree of contrast in length in the nearer side of different bands, which is transferred to the band widths; (iii) the inability to account for the whole projective transformation. To test these hypotheses, an experiment was conducted in which the shape of three stimuli was manipulated through affine transformation as well as variation of side lengths. The task of participants was to evaluate the width of the bands, by using four different methods of measurement. The results revealed a robust and stable illusory effect and confirmed the factors hypothesised by us.

◆ **The Poggendorff illusion in subjects in different psychophysiological states and various ways of presentation of the test figures**

I I Shoshina, L N Medvedev, R H Sharafutdinova (Krasnoyarsk State Pedagogical University, Lebedevoi 89, 660049 Krasnoyarsk, Russia; e-mail: shoshina@kspu.ru)

An attempt was made to estimate the contribution of physiological and psychological components to the Poggendorff illusion. Influence of the spatial arrangement of elements in the Poggendorff figure (Jastrow modification) and the way of its presentation on the frequency and magnitude of visual illusion was evaluated by using 24 spatial modifications. A group of ninety-five subjects was tested, both males and females, with different eye dominances and hand preferences and with varying levels of spatial cognitive ability development. The quantitative measure of psychological components of the illusion was the difference in the frequency of illusion when figures were presented randomly or in regular order. When random order of presentation was used, subjects perceived the illusion on average in 74.5% cases (both men and women). The frequency of the illusion did not depend on the type of eye dominance, or on the hand preference, or on the age of the subjects. At all ages, males perceived the illusion in a smaller number of cases. It is suggested that the perceived distortions in the Poggendorff figure have objective physiological basis, and in 30% of the cases the presence of this illusion depends on individual perceptual characteristics. [Supported by Krasnoyarsk Regional Fund for Science 15G008, SPU05-06-1/FP.]

◆ **The contribution of human brain areas to visual illusory effects. An fMRI-study on the illusory motion effect in the Pinna – Brelstaff figure**

U Budnik, P Bayerl¶, C H Attar§, B Pinna#, J Hennig‡, O Speck‡ (Department of Neurology and Neurophysiology [‡ Medical Physics, Department of Radiological Research], University Hospital Freiburg, Hugstetter-Strasse 49, D 79095 Freiburg, Germany; ¶ Department of Neural Information Processing, University of Ulm, Oberer Eselsberg, D 89069 Ulm, Germany; § Brain Research Unit, University of Freiburg, Hansastrasse 9a, D 79104 Freiburg, Germany; # Dipartimento di Scienze dei Linguaggi, Università di Sassari, via Roma 151, I 07100 Sassari, Italy; e-mail: ubudnik@yahoo.de)

In the Pinna – Brelstaff figure (PBF) an illusion of counter-rotating motion in two circles occurs when static patterns with specific luminance gradients are moved across the peripheral visual field during observer's self-movement towards or away from the figure. To create an illusion suitable for the MR scanner, computerised animation generated contraction and expansion of concentric circles of the PBF patterns on a screen. The visual illusory effect was quantified in each participant by nulling the illusory rotation effect in the PBF with counter-rotating motion. From these motion parameters correctly perceived rotating figures and a subjectively non-rotating PBF were created as a control individually for each subject. Sixteen volunteers with normal vision were tested at 3 T. A block design with randomised presentation order and full brain coverage EPI (1.7 mm × 1.7 mm × 3 mm resolution) was used. Both the illusory and the true rotation evoked increased activation within the motion-specific complex hMT+. The frontal eye fields and the Brocca homologue were found to be related to illusory rotation perception. When the real-stimulus-driven correct perception was compared with the illusory effect perception activations were found in the early visual areas, V1/V2.

Monday

◆ Illusory world in retinal coordinates

A Barlasov Ioffe, S Hochstein (Life Sciences Institute and Interdisciplinary Center for Neural Computation, Hebrew University, IL 91904 Jerusalem, Israel; e-mail: barlasov@pob.huji.ac.il)

Under certain conditions the retinal and the explicitly perceived image may differ. We replicated the experiment of Rock and Linnett (1993 *Perception* **22** 61–76), in which eye movements between sequential presentation of figure parts has this effect, by separating retinal and world coordinate representations. Can this separation be achieved in an image defined by illusory rather than real contours? To address this issue, we need, on the one hand, to test the presence of a retinal image and, on the other, to test its possible implications, ie to determine if this implicit information is available for perceptual processing. For the first, we implemented an afterimage procedure, while for the second we used a primed matching paradigm. Subjects looked at a moving fixation point on a computer monitor. Image components were flashed in appropriate locations relative to the moving fixation point and/or the fixed screen. Generally, the conscious percept combines the components relative to their absolute position on the screen. The retinal image, on the other hand, is always relative to the fixed or moving fixation point. There are separate explicitly perceived and implicit retinal images of an inducing pattern, though only the latter is available for real-shape match priming.

[Supported by an Israel Science Foundation “Center of Excellence” and the US–Israel Binational Science Foundation.]

◆ Interrupted side affects regularity of geometrical figures

M Sinico, G Parovel¶ (Department of Psychology, University of Bologna Alma Mater Studiorum, viale Berti Pichat 5, I 40127 Bologna, Italy; ¶ Communication Science Department, University of Siena, piazza San Francesco 8, I 53100 Siena, Italy; e-mail: michele.sinico@unibo.it)

When a side of a regular geometrical figure is interrupted, an illusory effect of irregularity can be perceived. The aim of our two experiments was to establish the influence of a spatial gap and of shrinkage by amodal completion on the perceived regularity of triangles. In the first experiment, we used an equilateral triangle with a gap in the base. The length of the sides was 8 deg. We manipulated the length (2, 2.5, 3 deg) and the position (0.6, 1.2, 1.8 deg from the base angles) of the gap. The adjustment method was adopted: ten subjects varied the horizontal position of the top angle until they perceived the shape to be regular. The results demonstrate that length and position of the gap influence the strength of the illusion. In the second experiment, we used, instead of a gap, an opaque rectangle. By amodal completion the base of the equilateral triangle was perceived to be complete. The results do not show a significant distortion of the triangle. A possible explanation is discussed, considering the role of the symmetry as the global factor, and the local effect of the inducer in relation to the Oppel–Kundt illusion.

◆ Perceived distortions of the straightness judgment

A Bielevičius, A Bertulis, A Bulatov, V Lasas (Department of Biology, Kaunas University of Medicine, Micevičiaus 9, LT 44307 Kaunas, Lithuania; e-mail: arubiel@vision.kmu.lt)

On the monitor screen, three light dots 1 min of arc in diameter were lined up horizontally with 60 min of arc intervals from each other. Three flanking horizontal stripes 1 min of arc wide and 10 min of arc long were combined in a stimulus: one stripe above or below the central dot, and the other two, respectively, below or above the end-dots with the same stripe-to-dot gap size. The central dot appeared to the subjects as shifted from the horizontal line. Using the panel keys, the subjects moved the central dot–stripe pattern up or down into a position in which the straight appearance of the three-dot stimulus was established. The dot-to-stripe gap was considered as an independent variable. The perceived distortions augmented regularly with an increase of the gap from 0 to 5–7 min of arc, reaching a maximum and then decreased monotonically approaching zero with further increase of the gap up to 12–15 min of arc. The experimental curves were symmetrical and showed opposite signs of the illusion for opposite positions of the stripes. The vertical and oblique orientations of the stimuli yielded qualitatively similar results.

PERCEPTION IN CONTEXT

◆ Influence of contextual stripes on perceived distortions of length matching

N Bulatova, A Bulatov, A Bertulis (Department of Biology, Kaunas University of Medicine, Micevičiaus 9, LT 44307 Kaunas, Lithuania; e-mail: bulatova@vision.kmu.lt)

In psychophysical experiments, subjects reported the two intervals of the three-dot stimulus to appear different in length in the presence of flanking stripes. The inside flanking stripes caused underestimation of the interval length, while the outside ones, conversely, induced overestimation.

To establish the perceived length equality, the subjects changed the test interval length disabling the physical matching. The length matching error varied with the height of the stripes: it augmented asymptotically approaching the maximum value 6%–12% of the reference interval length. When the empty gaps were formed within the central part of the stripes, the error decreased monotonously with increase of the gap size. The experimental findings show the presence of a certain positional averaging within the excitation areas, which have the Gaussian profiles. The results go in parallel with predictions of the weighted averaging model (Bulatov and Bertulis, 2004 *Informatica* **15** 443–454; Bulatov and Bertulis, 2005 *Acta Neurobiologiae Experimentalis* **65** 265–269): the excitation pattern of the focal stimulus is averaged with the excitation pattern of the contextual objects flanking the focal stimulus. In our experiments, positional averaging caused a shift of the perceived position of the end-points of the stimulus toward the position of appropriate flanking stripes.

◆ **Effects of contextual elements on vernier thresholds in peripheral vision**

B Sayim, M H Herzog (Laboratory of Psychophysics, Brain–Mind Institute, École Polytechnique Fédérale de Lausanne, CH 1015 Lausanne, Switzerland; e-mail: bilge.sayim@epfl.ch)

Processing of a target is often probed by impeding performance through neighbouring elements. For example, performance strongly deteriorates when a Vernier is flanked by two neighbouring lines. This deterioration is often explained by mechanisms based on local spatial interactions. In foveal vision, however, we could recently show that, if the number of flanks increased, performance improved, indicating global rather than local spatial processing (see Malania et al, 2006 *Perception* **35** Supplement, this issue). Here, we performed analogous experiments in peripheral vision. Stimuli consisted of a Vernier target presented at 4° eccentricity flanked on both sides by a variable number of lines. Distance between flanking lines was constant in all conditions. Verniers and flanking lines were randomly presented for 150 ms either to the left or to the right of a central fixation dot. Five well-trained subjects participated in the experiment. We found that an increase of the number of flanks first impaired and then improved performance. As in foveal vision, local spatial interactions cannot explain these results.

[Supported by the Swiss National Fund.]

◆ **Long-range facilitatory interactions in suprathreshold contrast perception**

L O Nurminen, P I Laurinen (Department of Psychology, University of Helsinki, PO Box 9, FI 00014 Helsinki, Finland; e-mail: lauri.o.nurminen@helsinki.fi)

The apparent contrast of a pattern can be enhanced by appropriate surround. In studies reporting enhancement surround has been presented near the centre; little is known about the effects of distance between the centre and the surround on contrast enhancement. We measured the apparent contrast of a sinusoidal circular (diameter 2.4 cycles) grating patch as a function of the distance between the centre and the surround. Spatial frequency of the stimuli was 3 cycles deg⁻¹ and the surround was 3 cycles wide. The distance between the centre and the surround was defined as the distance from the centre of the display to the midpoint between the outer and the inner radius of the surround. Five distances—3, 6, 9, 12, and 22.5 cycles—were used: centre contrast was 0.05, and surround contrasts were 0.016, 0.033, 0.066, and 0.1. At surround contrasts 0.066 and 0.1 a strong enhancement was evident even at 22.5 cycles. To our best knowledge this is the most distant enhancement reported. For the spatial frequency used here, this would be a distance of 7.5 deg. It is unlikely that these interactions could be accounted by summation to the excitatory mechanisms of population of V1 cells responding to the centre stimulus.

◆ **Centre–surround interactions in backward masking**

T P Saarela, M H Herzog (Laboratory of Psychophysics, Brain–Mind Institute, École Polytechnique Fédérale de Lausanne, CH 1015 Lausanne, Switzerland; e-mail: toni.saarela@epfl.ch)

Processing of visual features is affected by both temporal and spatial contexts. We studied the relationship between these two in backward masking. Contrast thresholds were measured for a foveal 4 cycles deg⁻¹ Gabor target (40 ms), which was followed by a mask (100 ms, either a grating disk, annulus, or a combination of them). With increasing mask size (orientation and spatial frequency matched to the target), thresholds first sharply increased, then decreased to an asymptotic level, still staying above the control (unmasked) level. To find the effects of mask distance, the inner diameter of an annulus mask was varied. Initially observed masking effect quickly dropped to zero as the diameter was increased. When a centre mask producing a large masking effect was combined with an annulus mask producing no effect at all, the effect of the centre mask was greatly reduced. Thus, the surround, by itself having no effect on the target,

Monday

nonetheless modulated the effect of the centre even in a backward-masking setting, where the target is presented before the mask. This surround effect was selective to orientation, spatial frequency, and spatial phase. The effects of a small gap between the centre and surround masks suggest an important role for mask homogeneity.

◆ **Activity evoked by a central moving stimulus depends on the direction of motion of a surrounding stimulus; an fMRI study**

C Moutsiana, D T Field, J P Harris ([Department of Psychology, University of Reading, Whiteknights, Reading RG6 6AL, UK; e-mail: c.moutsiana@rdg.ac.uk])

Motion outside the classical receptive field modulates single cell responses in area MT of monkeys (Allman et al, 1985 *Perception* **14** 105–126). What are the contextual influences on a population of visual neurons in human visual areas? We studied the effect of the direction of motion of a surrounding annulus on the BOLD activity associated with a moving stimulus inside the annulus. Concentric rings in the centre and the surround were shown alone or together, either expanding/contracting or static. Direction of surround motion was the same or opposite to that of the centre. Regions of interest (ROIs) were initially defined by the contrast moving centre > static centre, and then voxels were excluded if their activity was significant in the contrast moving surround > static surround. ROI clusters showed a significant increase in BOLD signal when the direction of the surround was opposite to that of the centre, and a significant suppression when the surround motion direction was the same as in the centre. When a 1.2 deg gap was inserted between centre and surround, similar effects of suppression and facilitation were found, suggesting that the lateral connections mediating surround motion effects in humans are more than 1 deg in length..

[Supported by a University of Reading Research Studentship and EPSRC.]

◆ **Implicit learning based on the semantic-category membership of the context**

A Goujon (Laboratoire de Psychologie Cognitive, CNRS, Université de Provence & INRETS, UMR 6146 Pôle 3C, Bâtiment 9, Case D, 3 place Victor Hugo, F 13003 Marseille Cedex, France; e-mail: goujon@up.univ-aix.fr)

Using the contextual cueing paradigm, Chun and Jiang (1998 *Cognitive Psychology* **36** 28–71) showed that contextual regularities can facilitate the search for a particular target via implicit learning mechanisms. In the present study this paradigm has been used to examine if regularities based on the semantic-category membership of the context can be learnt implicitly. Experiments were conducted with lexical displays. Half of the trials were 'predictive', ie the semantic-category membership of the contextual words (eg mammalian) predicted the target location, while the other half were 'non-predictive', ie the semantic-category membership of the contextual words (eg bird) did not predict target location. To ensure that semantic effects are indeed monitored, a transfer phase which used words that were different from those used in the first part of the task, was implemented during the search task. The results showed that performance was better in predictive trials than in non-predictive trials during the transfer phase, suggesting that contextual cueing can be generalised to new words. Furthermore, contextual cueing effects were indeed obtained implicitly. These findings suggest that implicit learning mechanisms which are based on semantic categories of contextual elements can guide attentional processes during the analysis of visual scenes.

◆ **Influence of visual field anisotropy on curvature extrapolation**

A Bertulis, L Mickiene, A Bulatov (Department of Biology, Kaunas University of Medicine, Mickievičiaus 9, LT 44307 Kaunas, Lithuania; e-mail: bertulis@kmu.lt)

The present data are concerned with accuracy of curvature extrapolation in dependence of stimulus orientation in the visual field. Subjects observed monocularly a segment of a circle formed of a bright line 3 min of arc thick, having a luminance of 10 cd m⁻² and presented against dark background. The segment size and position within the circle perimeter varied. The subjects forecasted the trajectory of the given segment by adjusting the position of the test-dot of 3 min of arc in diameter situated some distance apart from one end of the segment. They moved the test-dot with 0.3 min of arc steps along the circle radius forward or backward, placing it into point which corresponded to the intersection of the invisible radius and the trajectory of extrapolation. The obtained data have shown that the precision of curvature extrapolation depended on the meridian anisotropy of the visual field. The subjects showed a tendency to make the trajectories more flattened at the oblique positions (45°, 135°, 225°, and 315°) of the stimulus than at the horizontal (0° and 180°) or vertical (90°, and 270°) positions. The error magnitudes for horizontal and vertical positions were different. Also, the magnitudes differed for various oblique positions.

◆ **Catching patches: Filling-in between edges**

R van Lier, M L T Vergeer (Nijmegen Institute for Cognition and Information [NICI], Radboud University Nijmegen, PO Box 9104, NL 6500 HE Nijmegen, The Netherlands; e-mail: R.vanlier@nici.ru.nl)

The patches that appear at the crossings in the Hermann grid are known to disappear when the straight contours in the grid are distorted, eg by curvature (Geier et al, 2004 *Perception* 33 Supplement, 53). Here, we present an illusion based on Hermann-grid-like gratings in which the contours are randomly distorted. These distortions guarantee a severe reduction or complete disappearance of the visibility of the patches. Starting with these gratings we show that the patches at the crossings return when luminance edges are introduced and extended at the intersections. The 'returned' patches have the same relative lightness properties as they would have in a regular Hermann grid (dark patches when the crossing bands are relatively light, and light patches when the crossing bands are relatively dark). In addition, the polarity of the perceived lightness difference does not depend on the physical polarity of the edges (ie whether they are dark or light). A remarkable effect here is that at the crossings the whole area between the edges is perceived to have a different lightness, irrespective of the shape of that area (ie whether the edges bend inward or outward, etc). An experiment on perceived lightness differences confirmed the above observations.

[MV was supported by an NWO grant.]

◆ **Modulation of responses of simple and complex cells by differential contrast between centre and periphery of receptive fields in area 17 of the cat**

P-C Gillet, M Bouchard¶, S Shumikhina¶, S Molotchnikoff ¶ (Department of Physiology [¶ Department of Biological Science], University of Montréal, Montréal, Québec H3C 1J7, Canada; e-mail: pierre.camille.gillet@umontreal.ca)

Excitatory discharges evoked by stimulating the central part of classical receptive fields may be facilitated or inhibited by flanking targets. The sign of modulation depends on contrast in the excitatory centre: a weak contrast facilitates the response, a strong contrast inhibits it. We investigated these influences in a pool of units whose activity was simultaneously recorded. In cats, multi-unit recordings were performed in area 17. Cells were stimulated with a 50% contrast, central sine-wave patch and a peripheral patch (same orientation, luminance, spatial and temporal frequencies as the central patch) was applied. The contrast of the peripheral target was modulated from 0 to 100%. Single cells were sorted out from the multi-unit pool and the response magnitudes of individual cells were analysed in relationship to the differential contrast. Sorting out individual spikes from the original pool revealed that two neighbouring units react in different and sometimes opposite fashion to the same differential contrasts. In addition, complex cells seem to be sensitive to the contrast of the peripheral targets—specific differences in contrast facilitate discharges—whereas simple cells fail to show such sensitivity. Results suggest a coding process for contrast.

[Supported by NSERC.]

◆ **Visual object recognition: Priming of an object by the global organisation of the scene**

G Chaumet, S Delord¶ (Departement de Psychologie [¶ Laboratoire de Psychologie (EA 3662)], Université de Bordeaux 2, 3 place de la Victoire, F 33076 Bordeaux Cedex France; e-mail: guillaumechaumet@yahoo.fr)

We aimed to determine the facilitating effect of global organisation of the scene on the semantic categorisation of an object. In experiment 1, three types of primes were used: a control prime (a uniform gray), low-pass filtering of the scene, and the normal scene. The 128 objects were repeated in two blocks in which the types of prime and prime duration (200 ms, 800 ms) were varied. Results of the forty participants showed a priming effect on RT (−108 ms) restricted to the long duration of normal primes. In experiment 2, familiarity of the primes was increased by adding three preliminary blocks where the task was a semantic categorisation of the scenes (block 1), of the low-pass-filtered scenes (block 2), and of the filtered scene plus the objects (block 3). Block 4 was a replication of experiment 1, except that normal scenes were removed. Results of block 4 showed this time a priming effect of the object by the global organisation, whatever the duration. Taken together, the experiments showed that the global organisation could help the categorisation of an object, insofar as a representation of the scene is available.

Monday

IMAGE PROCESSING, APPLICATIONS, MODELS◆ **Robot visual sensing: Experience and future prospect**

V A Bunyakov, E I Urevich¶ (Television Systems, Central Research & Development Institute of Robotics and Technical Cybernetics [¶ RTC Department], Tikhoretsky pr. 21, 194064 St Petersburg, Russia; e-mail: bunyakov@rtc.ru)

The basic robot sensing method employs computer visual systems. Computer visual systems are used both in automatic control systems and in supervisory human-operator control systems. The main tendency in the evolution of such systems is the development of stereovision systems (including multiple-angle-shot computer vision systems). In such systems, the speed of reaction increases in the process of real-time recognition of complex patterns without the use of verbal information and creative thinking analogue implementation. The main task for the developers of the computer systems, as before, is creation of the ability of adaptation to various external factors (noise, illumination change, etc) to protect the system from outside disturbances.

◆ **Local descriptor groupings in reinforcement learning of sensory – motor attention**

L Paletta, G Fritz (Institute of Digital Image Processing, Joanneum Research, Wastiangasse 6, A 8010 Graz, Austria; e-mail: lucas.paletta@joanneum.at)

Previous research on behavioural modelling of saccadic image interpretation (Henderson, 1982 *Psychological Science* **8** 51–55) has emphasised the sampling of informative parts under visual attention to guide visual perception. We propose a system of sequential attention for object recognition that (i) groups n -tuples of local-gradient-based image descriptors (Lowe, 2004 *International Journal of Computer Vision* **60** 91–110) being scale-, rotation-, and to high degree illumination-tolerant, defining a vocabulary of prototypical code descriptors, (ii) selects only informative groupings for further processing, (iii) learns a predictive mapping from a current perceptual state in a Markov decision process to a next saccadic action, and (iv) present a model of object recognition being capable of integrating sequential information by minimisation of entropy in the Bayesian modeling of object hypotheses. The innovative abstraction level of informative groupings provides perceptual meta-states in sensory – motor attention, enabling the learning of a purposeful grammar integrating atomic feature – saccade mappings into a meaningful recognition behaviour. We demonstrate highly accurate recognition of outdoor facades in a mobile vision application, using the sensory – motor context of trans-saccadic object recognition.

◆ **Reinforcement learning for the selection of predictive cues in affordance-based perception**

L Paletta, G Fritz (Institute of Digital Image Processing, Joanneum Research, Wastiangasse 6, A 8010 Graz, Austria; e-mail: lucas.paletta@joanneum.at)

Human cognition embodies visual stimuli and motor interactions in common neural circuitry (Faillenot et al, 1997 *Cerebral Cortex* **7** 77–85). Affordances have been presented as a conceptual model of cued prediction for opportunities of agent – environment interaction (Edwards et al, 2003 *Brain and Cognition* **53** 495–502). Research for technical systems so far focused on determining simple feature – function relations heuristically, or highlighted the relevance of mapping from visual to haptic perceptual categories (Faag and Arbib, 1998 *Neural Networks* **11** 1277–1303). In contrast, we outline the relevance of reinforcement learning in determining a specific perceptual state that owns the predictive characteristics and the representation of an affordance-based visual cue. The learning process is applied to bridging two basic components characterising the interaction component ('affordance recognition': recognising relevant events in interaction via perceptual entities) and the predictive aspect ('affordance cueing': predicting interaction via perceptual entities), respectively. We illustrate in experimental results of a robotic system scenario how affordance recognition provides the reinforcement signal that is propagated back towards 'early' affordance cueing.

◆ **A category system on the shape index descriptor of local image structure induced by natural image statistics**

M Lillholm, L D Griffin¶ (The Image Group, IT University of Copenhagen, Rued Langgaards Vej 7, DK 2300 Copenhagen, Denmark; ¶ Computer Science, University College London, Gower Street, London WC1E 6BT, UK; e-mail: grumse@itu.dk)

Ecological statistics continues to serve as an important source of information and inspiration for vision research. In this work, we seek feature types that are induced by the statistics of natural images. As point of departure, we use the Gaussian derivative filters as a model of V1 simple-cell ensembles. Specifically, we focus on 2nd-order derivative filters. 2nd-order differential structure can be re-parameterised and qualitatively described through the shape index. Following Koenderink, we group image patches that are metamERICALLY equivalent—in this case have identical shape index. For each metamery class, a class representative is selected as the most likely among all collected patches and thus is not tainted by any models other than that implicitly

dictated by the distribution of natural image patches. Although the shape index spans a continuous real interval, our results show that maximum-likelihood 2nd-order natural image structure falls in one of only five qualitatively distinct categories: dark blobs, dark bars, saddles, light bars, and light blobs. Control experiments performed on Gaussian noise images and phase-randomised natural images give results that are in accordance with theoretical predictions and suggest that the main result is specific to natural images.

◆ **Synergetic model of recognition of Haken neural network**

D R Schwarz (Software Development Department, Research & Development Institute of Robotics and Technical Cybernetics, Tikhoretsky pr. 21, 194064 St Petersburg, Russia; e-mail: schwarz@rtc.ru)

The Haken neural network is based on synergetic principles. The network stores information between neurons. The proof of recognition works as follows. The presented image derives some images from the neural network. There is competition between them which results in one image (the reference image) prevailing. (Similar behaviour is observed in experiments with a boiling liquid, in which some vortices compete.) The attention parameter is active in the process of recognition, specifying which image is given the greater weight.

◆ **Benefits of exponent approximation of contrast sensitivity function for high spatial frequencies**

V E Doubrovski, A V Garusev (Department of Psychology, Lomonosov Moscow State University, Mokhovaya 8, Korpus 5, 103009 Moscow, Russia; e-mail: plumber@dubki.ru)

As long ago as 1965 Campbell and Green in their renowned paper pointed out that when plotting contrast sensitivity S on a logarithmic scale versus spatial frequency f on a linear scale, "... high frequency portion of the curve, from 10 c/deg on upwards, is closely fitted by a straight line. That is, the contrast sensitivity is decreasing exponentially with increasing spatial frequency." An approximation $S(f) = A \exp(-kf)$ depends on two parameters: A is the normalising coefficient, and k is supposed to be taken as a measure of attenuation. Contrast sensitivity function is commonly considered to be proportional to a modulation transfer function of visual system as a whole and should be a product of transfer functions of visual pathway elements. Using exponential approximations for these functions in the high-frequency range with appropriate $k[i]$, we could calculate k as a sum of $k[i]$. Surprisingly, we find that this approximation is almost never used to analyse experimental and theoretical data concerning visual acuity. We validated the approximation with a large set of our experimental data. Attenuation k between 0.09 and 0.16 was obtained with good correlation. We found that both theoretical and experimental transfer curves from different papers dealing with optical and retinal image distortions are well approximated by exponents.

◆ **A new and improved error-protection method in video transmission**

D N Vizireanu (Faculty of Electronics, Telecommunications and Informations Technology, Polytechnic University Bucharest, B-dul Iuliu Maniu 1–3, sector 6, RO 061071 Bucharest, Romania; e-mail: nae@comm.pub.ro)

A wavelet-based rate-scalable video codec is presented and an improved method of joint source–channel coding for efficient image and video data transmission over noisy channels is proposed. Simulation results show that the method outperforms previous work in this field which covered only coding with a fixed-length fractal code. The findings are discussed with regard to the real-time aspect of newly emerging systems for the protection of embedded-wavelet bit-streams against bit errors and packet erasures. When using a parametric model instead of the true operational distortion-rate curves, the Weibull model of the distortion-rate curve shows its superiority over previous models for real-time applications. Simulations indicate that when this parametric model is used instead of the true operational distortion-rate function, similar expected distortion is achieved, while, additionally, the real-time constraint is satisfied. Distortion-rate optimisation of the progressive error protection of embedded codes is discussed. A real-time algorithm searches for an error-protection strategy that minimises the average expected distortion over a set of transmission rates. Experimental results for a binary symmetric channel show that this approach achieves more efficient results than currently known solutions when both reconstruction quality and time complexity are considered.

◆ **Model-based generation of random stimuli and parameter analysis for the evaluation of print unevenness**

A Sadovnikov, L Lensu, J Kamarainen, H Kalviainen (Laboratory of Information Processing, Department of Information Technology, Lappeenranta University of Technology, PL 20, FI 53851 Lappeenranta, Finland; e-mail: Albert.Sadovnikov@lut.fi)

Print unevenness is one of the most important defects in modern printing technologies. Understanding the complete phenomenon of such low-contrast inhomogeneity requires reliable

Monday

analysis and modeling based on an experimental evaluation of visual perception. The evaluation, however, is not viable owing to the limited available characteristics of physical test prints and their reproduction methods. In visual-quality assessment problems, sample sets are limited to a narrow subset from an unknown distribution. Therefore, it is necessary to generate an artificial sample set covering a wider range of phenomenon instances with a possibility to control the sampling distribution. In this study, a process of generating random stimuli for the psychometric experiment of the evaluation of print unevenness is proposed and on the basis of this process a refined perception-model parameter analysis is performed. We extend Thurstone's law of comparative judgment to the continuous case, where the stimuli are not limited to a certain number, but generated according to a predefined distribution. The psychometric experiment results are further used in perception model parameter analysis and, consequently, a refined model is devised. The selected approach is suitable for cases where the range of the initial stimuli set is not wide enough for a reliable perception-model estimate.

◆ **Multiple-angle-shot computer vision systems. Future prospects**

A M Korsakov (State Scientific Center of Russia, Central R&D Institute for Robotics and Technical Cybernetics, Tikhoretsky pr. 21, 194064 St Petersburg, Russia;
e-mail: anton_korsakov@mail.ru)

Visual systems are an important source of information for both living organisms and engineering solutions like robotics. An important problem in the field of robot sensing is how to create a three-dimensional representation of the surroundings of the robot. A standard solution to this problem relies on the use of stereo systems. The use of stereo systems is limited by their poor accuracy at computing distances to an object. Computer vision systems using shots from several different angles provide a different solution for this problem. The difference in comparison with standard stereo systems is an increase in the points from which images of the scene are taken. The new systems offer new possibilities for the creation of three-dimensional images of objects and for the extraction of representations of the surrounding environment.

◆ **Simulation of the human vision system for monitoring moving objects**

A M Korsakov, A V Bakhshiev (State Scientific Center of Russia, Central R&D Institute for Robotics and Technical Cybernetics, Tikhoretsky pr. 21, 194064 St Petersburg, Russia;
e-mail: anton_korsakov@mail.ru)

A model of human retina is described. It includes three levels of vision information processing which are invariant to illumination changes in parts of the retina. On the basis of this model, illumination changes which are invariant to the motion of the detection system were produced. An integral computer model and a modeling interface were realised. The results show that an adaptive information processing system can be used for bionic models in a variable environment.

◆ **Computer simulation of attention fields in the task of image inspection and structural matching**

V R Lutsiv (Centre for Image Processing (Laboratory H-3601), Vavilov State Optical Institute, Birzhevaya linia 12, 199034 St Petersburg, Russia; e-mail: goi2006@vision.spb.ru)

The image inspection approach explored in our laboratory was inspired by the results of investigation of the attraction points of saccadic eye movements published by Zavalishin and Muchnik [1974 *Visual Perception Models and Image Analysis Algorithms* (Moscow: Nauka; in Russian)]. We modified the attractiveness function proposed in their book. This permitted our computer programs to fix the centre of attention field at the gravity centres (GC) of local image objects differing from their neighbourhood in average brightness. A straightforward extension of our approach is possible for dealing with local textures instead of local brightness. By centring the attention field at the GCs, we provided the possibility of immediate matching of the images subjected to affine transformation which are formed on retina if the rather flat surfaces are observed from long distances. The matching engine can estimate the values and directions of elongation of the chosen but not yet recognised image objects; thus the attention field takes the form of an ellipse encapsulating the object of interest and masking its neighbourhood. This permits us to select and isolate the images of separate homogeneous surfaces, each of which is then matched separately. The position and elongation parameters of each image of local surface are also used for structural matching of the image of scene as the whole.

◆ **Detection of moving objects by a digital-signal-processor-based automatic video surveillance system**

D N Stepanov (Software Development Department, R&D Institute of Robotics and Technical Cybernetics, Tikhoretsky pr. 21, 194064 St Petersburg, Russia; e-mail: dnstepanov@rtc.ru)

Detecting moving objects from a video sequence is a fundamental task in many computer-vision applications such as human detection and tracking, traffic monitoring, and military applications.

A common approach is to perform background subtraction, which identifies moving objects from the portion of a video frame that differs significantly from a background model. There are many problems which a motion-detection algorithm must deal with. First of all, it should avoid detecting non-stationary background objects such as swinging leaves, rain, snow, and shadows cast by moving objects. Secondary problems are camera sensor noise, small camera displacements, and changes in global scene illumination. The background model should react quickly to changes in background such as starting and stopping of vehicles, while the updating algorithm should not include foreground objects in the background model. Here, various background-removal algorithms for detecting moving objects in different video surveillance sequences are compared, starting with simple techniques such as frame differencing, and continuing to more sophisticated probabilistic modeling techniques. The general goal is to find a combination of techniques which can produce good results still being able to work in near-real-time at a digital-signal-processor-based video surveillance system.

◆ **Fixed pattern noise in natural visual system: a possible cause for contrast loss**

B Choubey (Department of Engineering Science, University of Oxford, Parks Road, Oxford OX1 3PJ, UK; e-mail: bhaskar@robots.ox.ac.uk)

Fixed pattern noise (FPN) is a well studied phenomenon in pixels of micrometer dimensions designed for typical cameras. This noise refers to the non-uniform response of a pixel array to uniform-intensity scenes, due to mismatch between devices used in these pixels, and leads to contrast loss in the imaging system (Choubey et al, 2004 *IEEE International Symposium on Circuits and Systems (ISCAS '04), Vancouver, 23–26 May* volume 4, pp 856–859). Using pictures captured by an uncorrected logarithmic camera, having a response function similar to that of human eye, I argue that photoreceptors in natural visual systems may have different responses to uniform intensities, in a way similar to that of artificial imaging systems, leading to FPN in these systems, and the visual system corrects for these non-uniformities either algorithmically or systematically. Further, either high amount of FPN or the failure of the visual system to correct for these non-uniformities may be one of the causes of contrast loss in conditions like amblyopia. Conclusions of unrelated physiological studies are also used to point towards non-uniform visual systems (Hofer et al, 2005 *Journal of Vision* 5 444–454).

◆ **Analysing the effect of filtering techniques on camera surveillance using eye movement recording**

M A Hogervorst¶, A I M Weitenberg, M P Lucassen¶ (TNO Human Factors, Kampweg 5 [¶ PO Box 23], Soesterberg, NL 3769 ZG Utrecht, The Netherlands; e-mail: maarten.hogervorst@tno.nl)

We evaluated the impact of filtering techniques (indicators showing the presence of potential events) on camera surveillance using eye movement recording. Live recordings were made of a square in Utrecht with 12 cameras during 2 hours. The recordings were shown in a control room with 8 monitors while observers could switch between cameras. The subject's tasks were: (i) report the cameras on which designated vehicles appeared, (ii) indicate the presence of cyclists, (iii) indicate changes in the people sitting on a concrete block. In one of the two sessions the subjects were supported by indicators showing the potential presence of vehicle movement, cyclist movement, block change events. We recorded the cycle events, block change events, the cameras on which the designated vehicles were reported, eye movements and camera switches. The results show that filtering has a positive effect on the time the vehicles were fixated, on the performance for indicating on which cameras the vehicles appeared, and on the performance for indicating block-change events. On the other hand, the subjects also followed the indicators in cases where their signals were not in accordance with reality. These findings show that the benefit of filtering in supporting camera surveillance depends on its reliability.

◆ **Optical veiling glare limitations to in-camera scene radiance measurements**

J J McCann, A Rizzi¶ (McCann Imaging, 161 Claflin Street, Belmont, MA 02478, USA; ¶ Department of Information Technology, University of Milan, via Bramante 65, I 26013 Crema, Italy; e-mail: ccanns@tiac.net)

Multiple exposure techniques improve the quantisation of pixel values in digital images and are claimed to extend the dynamic range of captured radiances. The combination of underexposed, normal, and overexposed images quantises more accurately images falling on the sensor. However, scene-image dynamic range on that sensor is controlled by veiling glare of the lens, light reflected inside the camera body, and light reflected off the sensor. The point-spread function of all cameras falls off very quickly with distance. This rapid decrease is offset by the millions of image pixels contributing small, but significant, glare to all other pixels. We made telephotometer

Monday

measurements from test scenes to accurately document the radiances in scenes. We used a variety of high dynamic range (HDR) calibration algorithms and evaluated their accuracy. In the worst-case scene, with a small opaque center and a large-high-radiance surround (ISO 9358:1994 standard for veiling glare measurements), camera veiling glare limits are reported to vary from 1% to 8% of the maximum radiance. That is, a film(sensor)-plane image dynamic range of only $\sim 25:1$. The presented data show that veiling glare is an image-dependent limit to in-camera radiance measurement of real-life scenes and must be taken into account in HDR natural images.

◆ **The foveola pixel discrimination and information capacity**

Y E Shelepin, S V Pronin (Pavlov Institute of Physiology, Russian Academy of Sciences, nab. Makarova 6, 199034 St Petersburg, Russia; e-mail: yshelepin@yandex.ru)

Discrimination of targets localised in the foveola, the central 20 min of arc of the retinal area, was measured. In the first experiment, a matrix of disks on a gray background was used. The size of the disks was 3 min of arc. The brightness of disks changed symmetrically from the gray equal to the background to white and black. The task of the observer was to discriminate whether the brightness of the disks varied. The human discrimination performance near the limit of resolution was extremely poor. The observer could discriminate only 2–4 levels of brightness of 20 disks presented in foveola. In the second experiment, the Mollon–Reffin Minimalist colour vision test was used to determine how successfully individuals can discriminate colour differences in the foveola. The size of disks was again 3 min of arc. In contrast to brightness discrimination, colour discrimination was much better according to the Mollon–Reffin test. These data contribute to our earlier experiments showing that performance of foveola amounts to 160–200 separate pixels, limited by point-spread function.

[Supported by RSSF grant 05-06-06085 and RFFR grant 05-04-49032.]

◆ **Shorter than you think? Temporal precision of visual stimuli on computer monitors: Pitfalls and systematic errors**

T Elze (Max Planck Institute for Mathematics in the Sciences, Inselstrasse 22, D 04103 Leipzig, Germany; e-mail: Tobias.Elze@mis.mpg.de)

Experiments in temporal aspects of visual perception like masking, priming, or flash-lag studies require a high temporal precision of the involved hardware since presentation lengths are at the millisecond level. An analysis of specified presentation lengths in visual masking experiments in *Vision Research* (2003–2006) revealed that about 40% of the authors used a measure for shortest stimulus presentation times which was unrelated to the actual times, with overestimations of several hundred percent. This study examines capabilities of the widely used CRT monitors with respect to their temporal precision. For accurate timing, a synchronisation of the video hardware signal to the vertical blank of the monitor is required. The time interval between two successive blanks is called ‘frame’. The commonly used number of frames is an inappropriate measure for calculating short presentation times and not related to the display time of a single pixel for single frames. Also, timing differences within one stimulus and between vertical and horizontal stimuli of the same length are demonstrated. CRTs oscillate and decay. The shape characteristics of phosphor decay are the crucial determinant of effective presentation length. It is suggested not to specify times in milliseconds but in frames together with the phosphor type of the monitor.

◆ **Computational study of the eye dynamics**

D-E Creanga, E M Ignat[¶] (Faculty of Physics, Biophysics and Medical Physics [[¶] Faculty of Theoretical Physics], University ‘Al. I. Cuza’, 11A blvd Carol I, RO 700506 Iasi, Romania; e-mail: dorinacreanga@yahoo.com)

The eye response to intermittent light was studied by computational methods based on specialised mathematical algorithms. The measurements were carried out at the eye surface with the use of adequate electric contact interfaces. Comparative study was accomplished on the temporal data series provided by the diurnal insect facet eye and human eye. The portrait in the state space and its fractal dimension, the Hurst exponent and the Lyapunov largest exponent revealed nonlinear features in the dynamics of both types of visual receptors. The Fourier transform and the autocorrelation time provided evidence of the strongest chaotic trend in the electric activity of the facet eye. The results provided by the analysis of the facet eye, more simple though similar in many respects to the vertebrate eye, suggest that the visual signal processing at the level of the second-order neurons is able to generate a dynamical component having a higher degree of complexity that we have detected at the eye exterior surface.

◆ **Modeling cortical maps with feedbacks**

P Kornprobst, T Viéville[¶], S Chemla[¶], O Rochel (INRIA, Odyssee Team [[¶]Odyssee Laboratory], 2004 route des Lucioles, BP 93, F 06902 Sophia-Antipolis, France; e-mail: Pierre.Kornprobst@sophia.inria.fr)

High-level specification of how the brain represents and categorises the causes of its sensory input allows to link ‘what is to be done’ (perceptual task) with ‘how to do it’ (neural network calculation). We show how to define the perceptual task as a an optimisation problem, and then we derive the related neural-network parameters considering regularisation mechanisms. The present contribution makes this framework explicit for a general class of vectorial, nonlinear map computations. Use of a scalar or vector map is an important feature when addressing the modelisation of cortical processing units such as cortical columns. Introducing nonlinear constraints between map components has several advantages—one is to take noisy measures into account, avoiding statistical bias, another is to define physical parameters with complex structure (eg 3-D orientation). In our context, we consider that neural-network information is mainly conveyed through spikes, and derive the spiking network parameters which implements the formalised processing. We consider SRM neurons with piecewise linear kernels and evaluate to which extent neuronal computations, such as winner-take-all or nonlinear filtering via anisotropic adaptative diffusion, is well formalised in such a context.

◆ **Statistical-mechanics modeling of rivalrous dominance and transition durations**

A J Noest, R van Ee (Department Functional Neurobiology, Utrecht University, Padualaan 8, NL 3584 CH, Utrecht, The Netherlands; a.j.noest@bio.uu.nl)

Spontaneous switching between incompatible percepts is broadly attributed to the eventual disruption of the current percept representation by neural adaptation and noise. Noise-perturbation experiments (Lankheet, 2006 *Journal of Vision* **6** 304–310) support this scenario, but it is ill-understood how natural adaptation and noise manifest themselves in the durations of percept dominance and (succesful, or failed) transitions (Brascamp et al, 2005 *Journal of Vision* **5** 1050a (abstract); Brascamp et al, 2006 *Journal of Vision* **6** 845a (abstract); Brascamp et al, 2006 *Perception* **35** Supplement, this issue), which have very different statistics. For dominance durations, we model the time-dependent rate of escape (via noise-induced nucleation) from the current percept attractor, while the slowly increasing adaptation is reducing the attractor ‘strength’. Adapting classical (Kramers) methods, we simplify the hazard function to its dominant three-parameter form, which allows us to find the closed-form solution for the durations distribution and its density. For transitions, we adapt the classical Maxwell construction in order to reduce the dominant transition-mode dynamics to a 1-D drift and diffusion between two absorbing walls. The corresponding Fokker–Planck equation can then be solved exactly in terms of Jacobi-theta³(3) functions, which are mathematically well studied, and for which fast numerical implementations are available in computer-algebra systems. This allows efficient fitting of our three-parameter model to the joint probabilities of durations of all (succesful or failed) transitions.

◆ **‘Motion-energy’ model of primary visual cortex micro-column**

S Capern, J Droulez, D Bennequin (Laboratoire de Physiologie de la Perception et de l’Action, Collège de France–CNRS, 11 place Marcelin Berthelot, F 75005 Paris, France; e-mail: simon.capern@college-de-france.fr)

An energy model for the analysis of motion in the primary visual cortex was introduced by Adelson and Bergen (1985 *Journal of the Optical Society of America A* **2** 284–299). Our approach is to show the correspondence between physiology and this kind of model. Using Adelson and Bergen’s idea of spatiotemporal motion energy, we propose a model of the functional organisation of a unit such as a micro-column of V1. The model assumes classical receptive fields for simple and complex neurons and incorporates a strong hypothesis about the distribution of the preferences of neurons in these populations. We make assumptions about the phase distribution, the nonlinear operator preferences, and the window of visibility (the preferences of neurons for frequency). In order to test our model, we used recent results and especially the optical imaging data of Basole et al (2003 *Nature* **423** 986–990), which show the influence of stimulus orientation, speed, and length on the population response of V1 neurons, and highlight the existence of a single cortical map of spatiotemporal energy.

◆ **Automatic image contrast enhancement**

M I Trifonov (I M Sechenov Institute of Evolutional Physiology and Biochemistry, Russian Academy of Sciences, Morisa Toreza 44, 194223 St Petersburg, Russia; e-mail: mtrifonov@bublik.com)

A method of automatic global contrast enhancement for increasing the perceived quality of an image is proposed. The method represents a three-step procedure of image brightness histogram

Monday

transformation. The first consists of sparing clipping of the histogram with its subsequent expansion to full dynamic range. The second deals with average image brightness adjustment. It is based on the well-known U-shaped behaviour of human threshold sensitivity, ΔL , in dependence on the mean surrounding brightness, L . At this point the image brightness is increased or decreased if average image brightness to be adjusted is lower or higher than some threshold. An empirical law for such image brightness adjustment is proposed. This procedure is equivalent to gamma-correction of an image, where an exponent value is automatically chosen according to the mean brightness of the original image. The final procedure represents nonlinear tilde-shaped transformation of the brightness histogram keeping the average brightness achieved in the second step. This procedure means compression/stretching of brightness middle tones and looks for a compromise between the global image contrast and the visibility of details in shadows and highlights. The method has been successfully tested on several image databases, and built in the photo-editing tool of Paint Shop Pro® (JASC Software Inc.).

◆ **Attentional effects on two stimulus afterimages: Theory and data**

G Francis, J Wede (Psychological Sciences, Purdue University, 703 Third Street, West Lafayette, IN 47906, USA; e-mail: gfrancis@psych.purdue.edu)

A pair of oriented gratings, shown for 1 s each, produces an afterimage of the first grating if the gratings are orthogonal. If the gratings have a parallel orientation, no afterimage is seen. We explain how this effect is due to the interaction of two types of after-responses in the visual system: one that codes opposite colours and one that codes opposite orientations. These two types of after-responses combine at a filling-in stage of the visual system, and produce a visible afterimage only when they are in spatial agreement. A quantitative simulation of a neural model of this process demonstrates how the after-responses combine. In this model, attention has been suggested to strengthen responses to orientation-sensitive cells. To further drive model development, we explored the effect of attentional focus on the first and second grating. Observers were assigned to one of four conditions where they were to focus attention on the first and/or the second grating. Attention does affect reports of the afterimage, with attentional focus on the second grating leading to more frequent reports of an afterimage.

◆ **Reverse-engineering computation of cortical maps of the visual brain by optical imaging**

P Kornprobst, F Chavane¶, S Chemla, A Reynaud¶, T Viéville (INRIA, Odyssée Team, 2004 route des Lucioles, BP 93, F 06902 Sophia-Antipolis, France; ¶ INCM, Équipe DyVA, UMR 6193, Bâtiment N, salle 030, CNRS & Université de la Méditerranée, 31 chemin Joseph Aiguier, F 13402 Marseille Cedex 20, France; Pierre.Kornprobst@sophia.inria.fr)

We asked whether optical imaging could be used to characterise the underlying computations, given the activity of a brain area. When biological neural-network information is mainly related to the synaptic input (thus to the membrane potential in this case), it is usually modeled by high-level representation of the related processing. For example, Viéville and Kornprobst [2006 *Proceedings of the 10th International Conference on Cognitive and Neural Systems (ICCNs), Boston, MA*] revisit the link between variational approaches, local diffusion mechanisms, and neural networks. This makes it possible to relate the observed activity to certain classes of underlying computations (eg early-vision processes, winner-takes-all mechanisms, etc). With this formalism, we propose to evaluate, given the activity of a spiking network measured by optical imaging (here during the observation of V1), which is the underlying diffusion process. This is a highly constrained mesoscopic model of neuronal activity, likely more robust to estimate here than in a less specific case. On the example of a very simple experimental paradigm, we analyse if the precision of the data is sufficient to estimate robustly the underlying diffusion mechanisms. More generally, we propose to estimate the required precision in terms of scale and dynamics for such a reverse-engineering paradigm to be valid.

◆ **Modelling fMRI edge responses in early visual cortex**

F W Cornelissen, T Vladusich (Laboratory for Experimental Ophthalmology and BCN Neuroimaging Center, School of Behavioural and Cognitive Neurosciences, University Medical Center Groningen, University of Groningen, PO Box 30.001, NL 9700 RB Groningen, The Netherlands; e-mail: f.w.cornelissen@rug.nl)

Neurons in the early visual cortex (V1/V2) tend to have relatively small receptive field sizes. The line-spread function of the BOLD signal has been estimated at about 3.5 mm full-width-at-half-maximum (FWHM). For these reasons, one would expect BOLD responses to be confined to the immediate vicinity of the neural source. Yet, we have found that the fMRI responses in these areas to 1 Hz contrast modulating luminance and colour edges are very wide. Here we show that such fMRI edge responses can be accurately modeled by the linear addition of an extended (FWHM

~16–20 mm) edge response in addition to a much narrower local one (~1 mm FWHM). Moreover, the narrow and extended-edge responses can be fitted with the same intercepts and slopes without affecting model performance. This latter result suggests that the local and extended-edge responses arise from highly correlated, if not identical, neural sources. The extended response may be related to ‘non-classical’ receptive field properties. Our findings have implications for fMRI studies of the role of V1 in perception. The use of regions-of-interest that are situated next to physically stimulated regions of the cortex may cause ‘spill-over’ of BOLD activity into non-stimulated regions, leading to erroneous inferences about perceptually related activity.

◆ **Can we recognise motion from spike train analysis?**

M-J Escobar, P Kornprobst, A Wohrer, T Viéville (INRIA, Odyssee Team,
2004 route des Lucioles, BP 93, F 06902 Sophia-Antipolis Cedex, France;
e-mail: Maria-Jose.Escobar@sophia.inria.fr)

We asked whether we are able to extract motion categorisation from the analysis of spike trains produced by a simulation of the MT area. To address this, we extended the retina spiking model of Wohrer et al (2005 *Perception* **34** Supplement, 235–236, in order to obtain a simplified model of MT, using spatiotemporal filters properly tuned for a certain range of speeds, and defined several channels for the different velocities with inter-inhibition. This simulation output is a sparse spatiotemporal spike train representation of the visual input. Following the preliminary work of Dimov et al (2005, in *Proceedings of the International Joint Conference on Neural Networks*) based on Giese et al biological motion and on recent results on rank-order coding, we propose biologically plausible distances between neural map activities. We introduce a generalisation of classifiers derived from the statistical learning theory (ie generalised SVM). We tested this framework to categorise motions in 40 videos. Our results reveal that motion category can be reliably estimated from the analysis of spike trains.

◆ **Responses of model V1 neurons to contrast stimuli with phase offsets: An evaluation of different tuning models for non-specific suppression**

J S Lauritzen, J Little¶ (Vision Science Research Group, School of Biomedical Sciences
[¶ Vision Sciences Department], University of Ulster, Cromore Road, Coleraine BT52 1SA,
Northern Ireland, UK; e-mail: js.lauritzen@ulster.ac.uk)

Contrast masking of a patch of grating by a larger grating of the same frequency and orientation is dependent on phase. When the test patch is near 90° out of phase with the mask, it appears that, psychophysically, Vernier localisation, rather than contrast processing, drives discrimination at threshold (Lauritzen et al, 2005 *Perception* **34** Supplement, 108). Vernier hyperacuity is thought to be mediated by responses of cells oblique to the line in which the offset is detected. Stimuli were generated, consisting of a large masking Gabor (mask) on which a smaller grating patch (test) was superimposed, at different test contrasts, and with different degrees of phase offset. A model (based on Lauritzen and Tolhurst, 2005 *Network* **16** 151–173) consisting of 128 model simple cells, tuned to 8 orientations, 8 spatial frequencies, and two phases, was used to evaluate the responses of the model cells at each point in the stimulus. The model shows that there is significant activation of model cells at 22.5° and 45° off the stimulus orientation. Divisive contrast normalisation improves the salience of these responses. Various physiologically plausible weightings for the normalising signal were applied to the model, and the results are compared to the psychophysical data.

◆ **Combined computer vision system for visually impaired people**

E V Isaev, A V Bakhshiev, A S Blochina, A M Korsakov (Central R&D Institute of Robotics
and Technical Cybernetics, Tikhoretsky pr. 21, 194064 St Petersburg, Russia;
e-mail: Isaev-Egor@yandex.ru)

The system is meant for increasing the safety of visually impaired people walking independently in unknown or changing situations, particularly in cities. The system is based on acquisition of 3-D imagery of the environment with two TV cameras and the transformation of this imagery to word description. The TV images from both cameras are transformed to digital format and then processed by stereovision methods: stereo matching of corresponding points in the images which allows calculation of the distances to these points, and their 3-D coordinates. Segmentation of the multiple found points in 3-D coordinates on the local subsets makes possible to associate each subset with a real object. Moreover, the system detects and tracks moving objects. The final task of the system is object recognition (tree, door, car, man, etc). The library of objects includes 3 kinds of simple objects (obstacle, hole, plane surface) and 20–50 kinds of real objects. Word description of the environment (distance and direction to obstacles, types of objects) and tonal signals (high-speed moving objects, risk of a collision with obstacles or falling into a hole) were all provided through headphones.

Monday

◆ **Visibility of targets in fog conditions with car headlights**

M Colomb, P Morange (Laboratoire Régional des Ponts et Chaussées de Clermont-Ferrand, 8–10 rue B. Palissy, F 63017 Clermont-Ferrand Cedex, France; e-mail: michele.colomb@equipement.gouv.fr)

Visual information is reduced in fog conditions, and, in particular, the contrast of objects when driving at night-time with car headlights. This impairment of vision may induce delay in the detection of obstacles and have negative impact on traffic safety. In order to investigate the visibility thresholds of targets in these conditions, we conducted experiments in a fog chamber using car headlights in comparison to a theoretical approach of using a model of vision developed by Adrian. Some targets have been placed at distances from 5 to 30 m from car with low beam, and an observer in driving position determined visibility thresholds. The luminance of the target and background were monitored by two photometers when changing fog density recorded by a transmissometer. Visibility criteria (such as contrast or visibility level) were determined for various angular sizes of the target related to the distance of observations. These experimental data were compared to the predicted values of luminance threshold determined by using the Adrian model, based upon Ricco's and Weber's laws. A comparison was made also with the experimental data of Aulhorn. Results are analysed for the specific situation of low luminance range, and improvements of the experimental procedure are proposed.

◆ **Several lightness induction effects with a computational multiresolution wavelet framework**

X Otazu, M Vanrell (Computer Vision Center, Campus UAB, Bellaterra, E 08193 Barcelona, Spain; e-mail: xotazu@cvc.uab.es)

Lightness induction effects are provoked in the human visual system by the interactions between an observed central stimulus and its surround information. Depending on different properties of both, central and surround stimuli, several induction effects may appear, such as lightness assimilation or lightness contrast. In computer vision some efforts are devoted to reproduce induction effects on digital images, with the final goal of building perceived images as the basis for further processing, such as quality control or general image understanding. Multiresolution decomposition has been shown in many works as a general framework to reproduce perceptual induction processes in a unified formulation (Blakeslee and McCourt, 2005 *Vision Research* **45** 607–615) (Otazu and Vanrell, 2005 *Journal of Imaging Science and Technology* **49** 262–271); it has been essentially applied to reproduce assimilation and contrast effects. In this work we present a computational multiresolution wavelet framework which describes assimilation and contrast effects in a unified formulation. Moreover, it makes it possible to reproduce other common visual effects such as the White effect, Mach bands, Chevreul effect, Adelson–Logvinenko snake, the Schyns and Oliva faces, and the Hermann–Herring effect in a very unified and simple model. This wavelet framework is based on the definition of a surrounding induction function that recovers the induced image from the coefficients of the computed multiresolution decomposition.

◆ **A biological model of low-level vision suitable for image analysis and cognitive visual perception**

N Guyader, A Chauvin¶, C Massot, J Hérault, C Marendaz§ (Laboratoire des Images et des Signaux, INPG, 46 avenue Félix Viallet, F 38031 Grenoble Cedex, France; ¶ Ureca–Lille3, Domaine Universitaire du Pont de Bois, BP 149e, F 59653 Villeneuve d'Ascq Cedex, France; § Laboratoire de Psychologie & NeuroCognition (CNRS UMR 5105), Bâtiment Sciences de l'Homme et Mathématiques, BP 47, F 38040 Grenoble Cedex, France; e-mail: nathalie.guyader@lis.inpg.fr)

In the framework of biological models of vision, we assume that the outputs of complex cells of the visual cortex are suitable for analysing local and global properties of the retinal image. These outputs sample the local Fourier amplitude spectrum of images. We propose a model of the first stages of human visual system that provides efficient image-description features. These features are insensitive to a large number of variations: illumination (solved by the retinal preprocessing), spatial position (solved by local Fourier amplitude spectrum), image scale and rotation (solved by biologically plausible log-normal filters in lieu of the classically used Gabor filters). The model output is compared to the results of a psychophysics experiment. This comparison both provides explanations of perceptual mechanisms in terms of the structure of the model; and reciprocally suggests model improvements, eg by choosing more diagnostic filters to suit images and/or tasks. We are using this model in various image-analysis applications such as categorisation, extraction of salience maps, or local estimation of perspective. The model predictions are confirmed by the behaviour of observers, either when categorising natural scenes under various conditions: rotation, image size, and screen distance; or when estimating 3-D texture orientations.

◆ **The 2nd-order local-image-structure solid**

L D Griffin (Department of Computer Science, University College London, Gower Street, London WC1E 6BT, UK; e-mail: l.griffin@cs.ucl.ac.uk)

Gaussian derivative filters are a good model of V1 simple cells and their action can be interpreted in the framework of differential geometry. Six such filters can together probe local structure up to 2nd order. The 6-D space of their joint outputs was factorised by the action of a group of transformations that leave intrinsic image structure invariant. The group is generated by: spatial translation, rotation and reflection, and increasing linear transformations of intensity. The resulting factored space is a 3-D bounded orbifold. The orbifold has non-flat intrinsic curvature, but a volume-preserving, mildly distorting (mean 20%) embedding of it into Euclidean 3-space was found. The embedded orbifold has been named the 2nd-order local-image-structure solid. It is shaped like a lemon, half-flattened so that it has two creased edges running between two sharp points. The two points correspond to umbilic extremum. One crease corresponds to the varieties of pure 2nd-order structure (extrema, saddles, and ridges), the other to mixtures of an umbilic extremum and a plane. The solid can be used in the study of image statistics. For example, the histogram of local 2nd-order forms for natural images shows a clustering of density around effectively 1-D local forms.

[Supported by EPSRC grant EP/D030978/1 'Basic Image Features'.]

◆ **Multi-local dependencies of gradient directions in natural images**

A J Nasrallah, L D Griffin (Department of Computer Science, University College London, London WC1E 6BT, UK; e-mail: a.nasrallah@cs.ucl.ac.uk)

The perceptual processes by which image elements are grouped into Gestalts may be informed by the particular multi-local statistical regularities that natural images exhibit. To investigate this, we are searching for these multi-local regularities. We define multi-local to mean local measurements made simultaneously at multiple locations in an image; for example, triples of gradient directions at multiple locations. We have used information-theoretical measures to compute the amount of multi-local dependence which exists between gradient directions at two and three locations. We consider gradient directions because they are the natural next choice after luminance, and the correlation between pairs of pixel intensities is already well-known for natural images. We have studied multi-local dependences in natural images, their phase-randomised and whitened versions, and Gaussian noise images. We found that the dependences for natural images and their phase-randomised counterparts are the same, but different from those of whitened natural images and Gaussian noise images, which are also the same. From these and other results we conclude that: (i) for individual images the power spectrum approximately determines the multi-local dependences and (ii) for ensembles of images the mean power spectrum precisely determines the mean multi-local dependences.

[Supported by EPSRC Studentship.]

TUESDAY

ORAL PRESENTATIONS

THE GATE OF PERCEPTION: INFORMATION TRANSFORMATION IN THE LGN

◆ **Cortical control of retino-geniculate transmission**

K Funke (Department of Neurophysiology, Ruhr-University Bochum, Universitätsstrasse 150, D 44780 Bochum, Germany; e-mail: funke@neurop.rub.de)

Transmission of visual signals through the lateral geniculate nucleus (LGN) is not a simple relay of activity. Histological, electrophysiological, and model studies have demonstrated that retino-geniculate transmission is under the control of local and remote neuronal circuits, one originating in layer 6 of cortical areas 17, 18, and 19 and terminating at the relay cells itself and at local inhibitory interneurons and GABAergic neurons of the perigeniculate nucleus. The function of the cortico-geniculate feedback system cannot be described simply by one mechanism. A couple of studies have shown that it modulates a number of different aspects of how geniculate relay cells respond to the retinal input. These include changes in the gain of retino-cortical transmission, in the spatial properties of receptive fields, and in the temporal structure of visually induced spike activity. On one hand, the cortical feedback seems to tune geniculate relay cells for distinct stimulus features like the orientation of contrast borders and orientation contrast. On the other hand, it changes the strength and temporal structure of visual activity in a way allowing for enhanced processing of visual details in a focus of attention but also re-directing this focus to other salient stimuli in a bottom-up manner.

[Supported by the Deutsche Forschungsgemeinschaft (SFB 509, TP A2, A4).]

◆ **Cholinergic modulation of neural processing in the dorsal lateral geniculate nucleus**

P Heggelund (Institute of Basic Medical Sciences, University of Oslo, POB 1103 Blindern, N 0317 Oslo, Norway; e-mail: paul.heggelund@medisin.uio.no)

Our research group has over the past few years been engaged in several studies on cholinergic modulation of response properties of neurons in the dorsal lateral geniculate nucleus (dLGN), and this presentation gives an overview of our main findings. In intact, anesthetised cats we studied the effects of increased levels of acetylcholine (ACh) on response properties of single units to visual stimulation. We analysed the effects on spatial receptive field organisation, response gain, and response variability of both nonlagged and lagged cells. Increased levels of ACh were induced by electrical stimulation of a peribrachial region of the brain stem (PBR) that contains cholinergic neurons projecting to dLGN, or by local ionophoretical application of ACh. In brain slices from rat we studied cholinergic effects on cellular properties of single neurons with special emphasis on intrinsic interneurons. We analysed effects of muscarinic receptor activation on electrotonic properties and shifts of firing pattern from burst to tonic mode in the interneurons. Furthermore, we studied effects of muscarinic receptor activation on types of inhibition evoked in thalamocortical cells by the interneurons.

◆ **The influence of synaptic background activity on the spike transfer from thalamus to cortex**

J Wolfart, D Debay¶, G Le Masson§, A Destexhe¶, T Bal¶ (Neurozentrum, Department of Neurosurgery, University Hospital Freiburg, Breisacher Strasse 64, D 79106 Freiburg, Germany; ¶ Unité de Neurosciences Intégratives et Computationnelles, CNRS-UPR 2191, F 91198 Gif-sur-Yvette, France; § INSERM U378, Université de Bordeaux, 1 rue Camille Saint-Saens, F 33077 Bordeaux, France; e-mail: jakob.wolfart@uniklinik-freiburg.de)

Characterising the responsiveness of thalamic neurons is crucial for understanding the flow of sensory information. Typically, thalamocortical neurons possess two distinct firing modes. At depolarised membrane potentials, thalamic cells fire single-action potentials and faithfully relay synaptic inputs to cortex. At hyperpolarised potentials, the activation of T-type calcium channels promotes burst firing, and the transfer is less accurate. Our results suggest that this duality no longer holds if synaptic background activity is taken into account. By injecting stochastic conductances in guinea-pig thalamocortical neurons in slices, we showed that their transfer function is strongly influenced by conductance noise. The combination of synaptic noise with intrinsic properties gives a global responsiveness, more linear, mixing single-spike and burst responses at all membrane potentials. As in thalamic neurons, background synaptic input originates mainly from cortex; these results argue for a determinant role of corticothalamic feedback during sensory information processing.

[Supported by Centre National de la Recherche Scientifique, Human Frontier Science Program, European Commission (IST-2001-34712), Action Concertée Incitative Neurosciences Intégratives et Computationnelles, and European Union Marie Curie fellowship to JW.]

◆ How the LGN transforms retinal information

A R R Casti, Y Xiao, E Kaplan (Department of Neuroscience, Mail Box 1218, Mount Sinai School of Medicine, 1 Gustave L Levy Place, New York, NY 10029, USA; e-mail: acasti@gmail.com)

An intelligent design of the brain requires that the LGN should preserve most of the information assembled by the retina. However, the firing rate of LGN relay cells is significantly lower than that of the retinal ganglion cells that drive them, and they typically only block retinal spikes without adding new ones. The blocked spikes must, therefore, be less informative. How is this selection of spikes that are to be relayed to the cortex accomplished? We have investigated this and related questions in paralysed and anaesthetised cats. We recorded the retinal input (as S potentials) together with the LGN output, and compared the information rates and other properties of the retinal spikes that failed to elicit LGN spikes with those that were successful. We investigated the influence of the cortico-thalamic feedback with visual stimuli that engage the feedback to varying degrees. We found that the retinal spikes that the LGN did not relay to the cortex differed from the ones that were passed on to the cortex: they carried less information and followed fainter features of the stimulus. It is likely that other parts of the circuit, especially the cortical feedback to the LGN, participate in the selection process. [Supported by NIH grants 1R01 EY016371 and 1 K25 MH67225-03.]

◆ Mechanistic modeling of signal processing in the LGN circuit

G T Einevoll (Department of Mathematical Sciences and Technology, Norwegian University of Life Sciences, N 1432 Aas, Norway; e-mail: gaute.einevoll@umb.no)

The difference-of-Gaussians (DOG) model is an example of a descriptive receptive-field model, mainly aimed at compact representation of experimental response data. Mechanistic receptive-field models, on the other hand, aim to account for neuronal response properties based on knowledge of the underlying neural circuitry. The physiological properties of the neurons in the LGN circuit and their synaptic connections are at present fairly well mapped out, allowing for the tentative development of such models. Here, various mechanistic models for the LGN relay-cell receptive fields are presented and discussed including (i) a purely spatial feedforward model encompassing direct excitation from retinal ganglion cells and indirect inhibition via intrageniculate interneurons (Einevoll and Heggelund, 2000 *Visual Neuroscience* **17** 871–886) and (ii) comprehensive spatiotemporal models also including the effect of linear (Einevoll and Plesser, 2002 *Network – Computation in Neural Systems* **13** 503–530) or nonlinear corticogeniculate feedback. The models are compared with various experimental data with the use of flashing-spot, drifting-grating, or bipartite patch-grating stimuli.

MATCHED FILTERING IN HUMAN VISION

◆ Mismatched filtering

W McIlhagga (Department of Optometry, Bradford University, Bradford BD7 1DP, UK; e-mail: w.h.mcilhagga@bradford.ac.uk)

Matched filtering provides a useful departure point for theories of perception. However, the human visual system is probably better described as a kind of mismatched filter. McIlhagga and Paakkonen (1999 *Vision Research* **39** 367–372) introduced the noisy-template model, in which a matched filter (or template) is stochastically mismatched by adding noise to it. The additive noise acts as an average of all possible mismatches of the filter. Noisy filters provide an interesting account of area summation and contrast discrimination (Weber's law) and are successful at accounting for the effects of contrast on Vernier acuity. However, the additive noise has some implausible properties. Here, I discuss a new stochastically mismatched filter—the sampled template. This model begins with an ideal matched filter for the perceptual task, which is then represented as a sum of primitive filters (eg Gabors, wavelets, receptive fields). The sampled template is a random subset of these primitive filters, where the random subset varies from trial to trial. The sampled-template model accounts for the same phenomena as the noisy template, has a more plausible mechanism, and additionally accounts for some effects of learning and attention.

◆ What pattern does the visual system detect best?

A J Ahumada, L F V Scharff[¶], A B Watson (NASA Ames Research Center, MS 262-2, Moffett Field, CA 94035, USA; [¶]Department of Psychology, Stephen F Austin State University, Box 13046, SFA Station, Nacogdoches, TX 75962, USA; e-mail: al.ahumada@nasa.gov)

Watson et al (1983 *Nature* **302** 419–422) showed that the highest quantum efficiency of spatial pattern detection occurs when the contrast energy threshold is lowest. They searched through a number of spatial-temporal stimuli and found a drifting Gabor to be the best pattern.

The Modelfest data set has 43 different images whose detection thresholds have been measured for 16 observers from several different laboratories. The two images with the lowest contrast energy thresholds are a one-octave-bandwidth Gabor patch at 4 cycles deg^{-1} (similar to the Watson et al result) and a Gaussian blob with a standard deviation of 2.1 min of arc. When contrast sensitivity is compensated for (Watson, 2000 *Optics Express* 6 12–33; Watson and Ahumada, 2005 *Journal of Vision* 5 717–740), the best Gaussian blob is the smallest one (1.0 min of arc) and the overall best stimulus is the smallest Gabor, the one-octave-bandwidth patch at 16 cycles deg^{-1} . A long (1 deg), thin line image is now almost as good as these best stimuli. We find that lines in the 5 to 25 min of arc range can be detected as well as the best patterns. [Supported by FAA/NASA DTFA-2045 and NASA Airspace Systems.]

◆ **Models of the human visual system based on matched filtering**

N N Krasilnikov, Y E Shelepin¶, O I Krasilnikova (Department of Information and Network Technologies, State University of Aerospace Instrumentation, Bolshaya Morskaya 67, 190000 St Petersburg, Russia; ¶ Pavlov Institute of Physiology, Russian Academy of Sciences, nab. Makarova 6, 190034 St Petersburg, Russia; e-mail: nnkk23@aanet.ru)

Our aim is to review investigations in the area of matched filtering in the human visual system (HVS). At the end of the 1950s the hypothesis about matched filtering of images in HVS with their detection and identification in threshold conditions was formulated and proved experimentally (Krasilnikov, 1958 *Tekhnika Televideniya* 25 26–43). The applicability of this approach for identification of images of different complexity—from Landolt C to the human faces, coloured, dynamic and 3-D images—has been demonstrated. On the basis of statistical decision theory and an HVS model based on matched filtering we derived main HVS laws that have been known earlier only as empirical ones. In our model implemented as software we can set parameters defining the conditions of observation. Our model takes into account the real physiological mechanisms of fast and slow adaptation at the retina level and of the memory in higher HVS levels. The efficiency of HVS and characteristics of internal noise in healthy observers and in patients with neurotic type of mental disorders have been found.

◆ **Limited flexibility in the filter underlying saccade target selection: Effects of spatial scale and eccentricity**

C J H Ludwig, M P Eckstein¶, B R Beutter§ (Department of Experimental Psychology, University of Bristol, 12A Priory Road, Bristol BS8 1TU, UK; ¶ Department of Psychology, University of California at Santa Barbara, Santa Barbara, CA 93106, USA; § NASA Ames Research Center, Moffett Field, CA 94035-1000, USA; e-mail: c.ludwig@bristol.ac.uk)

The choice where to direct a saccadic eye movement depends on visual processing of information from potential target locations. Matched filtering is one possible strategy for saccade target selection: the observer matches the signal at each possible location with a filter, and fixates the location that triggered the largest internal response. Observers were presented with four equally eccentric Gaussian patterns in spatially uncorrelated Gaussian noise. Their task was to choose the pattern with highest contrast. We varied the eccentricity and spatial scale of the patterns. The underlying filter was estimated through reverse correlation of the noise at the landing position of the first saccade. Our results showed that the filter (i) had inhibitory lobes flanking an excitatory centre; (ii) was imperfectly adjusted to the spatial scale of the patterns; and (iii) remained nearly constant up to an eccentricity of 9°, despite considerable performance variations with eccentricity. The spatial integration window underlying saccade target selection can be flexibly adjusted according to the task demands, although we have demonstrated clear limits to this flexibility. Such limits reflect the extent to which the neural circuitry involved in programming saccadic eye movements is able to appropriately weigh and combine outputs from earlier visual mechanisms.

[Supported by EPSRC.]

◆ **Probing the templates for face perception with ‘totem poles’**

M A Webster, S M Webster, K McDermott, S Shumaker (Department of Psychology, University of Nevada in Reno, Reno, NV 89557, USA; e-mail: mwebster@unr.nevada.edu)

A strong impression of a face can often be elicited by random or natural images, which suggests that the stimulus requirements for perceiving a face are relatively simple. However, the nature of these requirements is not well characterised. We used symmetric $1/f$ noise patterns to probe which image properties give rise to the percept of a face and the relative importance of different properties. Vertical symmetry can lead to the appearance of many stacked and overlapping faces reminiscent of a totem pole. Observers labeled these by outlining each apparent face and its elements on the image, and also described the characteristics of the face, including its salience

in the image and whether it appeared human. By sampling the faces perceived along the poles over many images, we measured the distribution of featural and configural properties that could support face perception. This analysis highlights the importance of several stimulus dimensions including symmetry, orientation, and contrast polarity in face perception, as well as pointing to the necessary configural arrangements of features. Such measurements may help reveal the basic perceptual templates for face coding.

[Supported by grant EY10834.]

TIME AND TIMING IN BIOLOGICAL SYSTEMS

◆ The topological approach to temporal organisation

L Chen (State Key Laboratory of Brain and Cognitive Science, Institute of Biophysics, Chinese Academy of Sciences, 15 Datun Road, Beijing 100101, China; e-mail: cl@cogsci.ibp.ac.cn)

To address the fundamental question of what are the primitives of visual perception, a theory of early topological perception has been proposed. It holds that a primitive and general function of the perceptual system is the perception of topological properties. The topological approach is based on a core idea, namely that perceptual organisation should be understood in the perspective of transformation and perception of invariance over transformation. Thus, the topological approach highlights the relation of spatial organisation and temporal organisation, namely that shape-changing motion introduces the time domain. In the time sequence with shape-change, the seemingly static issue of holistic perception becomes a temporal issue—percept of the identity of the object over time—indicating that the mechanism of holistic perception needs to be understood not only from the perspective of spatial organisation but essentially from the perspective of temporal organisation. This analysis leads the topological approach to tie a formal definition of an 'object' to invariance over topological transformation. Further empirical data supporting the topological definition of perceptual objects in the studies of pre-cueing selective attention, multiple object tracking, and capture attention are presented.

◆ Temporal-order judgment across the lifespan

E Szegel, A Szymaszek¶, I Kolodziejczyk¶ (Nencki Institute of Experimental Biology [¶ Laboratory of Neuropsychology], Warsaw School of Social Psychology, Chodakowska 19/31, PL 03815 Warsaw, Poland; e-mail: e.szegel@nencki.gov.pl)

We review the results of our studies on the effect of subject's age and gender on sequencing abilities. The research addresses temporal-order threshold (TOT), ie the minimum time interval between two successive stimuli necessary for a subject to report correctly her/his temporal order. We studied in total 247 healthy volunteers, ranging in age from 20 to 100 years. TOTs were assessed by: (i) binaural presentation of two tones of different frequencies; (ii) monaural presentation of two clicks or identical tones, presented with varying interstimulus intervals (ISIs). Both an adaptive procedure and constant ISIs were applied; the task was to identify the order of presented stimuli. The results showed that the TOTs increased with subject's age; also they were lower in men than in women. A considerable deterioration started in subjects older than 60 years and was very pronounced in centenarians. In general, monaural presentation resulted in lower TOTs than the binaural one. Moreover, TOTs were lowered by listener practice. These results do not support the old hypothesis of one mechanism that controls our sequencing abilities, but suggest that this mechanism is strongly related to age, gender, procedure, and practice.

[Supported by KBN grants: PBZ-MIN/001/P05/06) and PBZ-KBN-022/PO5/1999.]

◆ Age-related differences on the timing of inhibitory mechanism of attention

Y Bao, L Fu¶, X Xiao, X Wang, J Zhou¶ (Department of Psychology, Peking University, Beijing 100871, People's Republic of China; ¶ Institute of Developmental Psychology, Beijing Normal University, Beijing 100875, People's Republic of China; e-mail: baoyan@pku.edu.cn)

Immediately following a noninformative peripheral cue there is facilitation for the processing of a target at that cued location. This process is believed to reflect an automatic capture of attention by peripheral stimulation. However, when the time lag between the cue and the target is prolonged, the early facilitation is reversed to an inhibition; a delayed responding to targets appear at the cued location relative to the uncued location. This late inhibitory effect is termed inhibition of return (IOR) and is generally considered as an inhibitory mechanism that delays attention from returning to a previously attended location so as to encourage orienting towards novel locations. Previous studies have shown that IOR is a robust phenomenon that can be observed not only in normal young adults, but also in elderly people and even in newborns. Here we present results of a series of experiments examining the time course of IOR in different age groups: children, adolescents, young adults, and elderly people. We found that the onset of IOR developed earliest in young adults, later in elderly people, and last in young children and adolescents, showing the age-related differences on the timing of inhibitory mechanism of attention.

◆ **Nonlinear properties of V2 and V4 neurons emerge in multi-layer networks trained with natural images**

C Zetzsche, U Nuding¶, K Schill (FB 3 Cognitive Neuroinformatics, University of Bremen, PO Box 330 440, D 28334 Bremen, Germany; ¶ Bernstein Center for Computational Neuroscience, Universitätsklinikum München-Großhadern, Ludwig-Maximilians-Universität, Marchioninistrasse 23, D 81377 Munich, Germany; e-mail: zetzsche@informatik.uni-bremen.de)

We investigated nonlinear multi-stage networks optimised to reduce statistical dependences in natural images. These networks serve as models for the neural information processing in the higher visual areas of primates (visual cortices V2, V4). We analysed the resulting units with regard to nonlinear selectivity and invariance properties. We show that the proposed network principle leads to units that are highly selective with respect to the input signal space and to units that are invariant with respect to certain stimulus classes. The stimulus selectivity is tested by a set of Cartesian, hyperbolic, and polar gratings as used in several physiological experiments. We compared the population histogram of the stimulus selectivity indices of the network units with the population histogram of macaque V2 units and show that the network can achieve the high selectivity observed in many V2 neurons. We also tested for nonlinear frequency interaction effects, and found substantial interactions for frequencies with the same orientation and for frequencies with different orientations. The former enable a selective encoding of edges and the latter are required for the selective encoding of intrinsically two-dimensional features like corners and terminators.

[Supported by DFG (SFB TR 8 Spatial Cognition) and by Bernstein Center for Computational Neuroscience (BMBF) Munich 01G0440.]

◆ **Temporal characteristics of the human visual field**

H Strasburger¶, D A Poggel#§, W Eisenbarth#, B Treutwein‡, M MacKeben◇
(¶ Department of Medical Psychology, University of Göttingen, Waldweg 37, D 37073 Göttingen, Germany; § Generation Research Program [GRP], University of Munich, Professor-Max-Lange-Platz 11, D 83646 Bad Tölz, Germany; # Boston VA Medical Center, Mail Stop 151 E, Room 8B-70, 150 South Huntington Avenue, Boston, MA 02130-4893, USA; ‡ IuK, Ref. III A 3, University of Munich, Geschwister-Scholl-Platz 1, D 80539 Munich, Germany; ◇ Smith-Kettlewell Eye Research Institute, 2318 Fillmore Street, San Francisco, CA 94115, USA; e-mail: strasburger@uni-muenchen.de)

Visual performance is distributed unevenly across the visual field, the fovea often showing best performance. Whereas the topographies of spatial and intensity characteristics are well studied, fewer data exist on temporal characteristics of information processing across the visual field. We present data sets from several studies measuring Treutwein's double-pulse resolution (DPR), high-resolution reaction time (RT), static perimetry, and movement contrast sensitivity (movCS, for moving plaids). These topographical, normative data were acquired across the lifespan up to the age of 90 years for assessing performance in patients with cerebral visual field loss or age-related maculopathy (ARM). Key findings are: (i) DPR thresholds with constant-size stimuli increase with eccentricity by ~ 1 ms per degree. (ii) RT increases by ~ 2.8 ms per degree eccentricity. (iii) movCS declines by $0.01 - 0.03 \log_{10}$ units per degree with eccentricity and $0.01 \log_{10}$ units per year. (iv) DPR correlates substantially with perimetry ($\rho = 0.52$) but little with RT ($\rho = 0.28$). (v) All performance parameters correlate substantially with age (DPR: $\rho = 0.65$; RT: $\rho = 0.28$; PER: $\rho = 0.71$). However, up to the age of 60–70 years, loss of performance is shallow and age-related changes are smaller than inter-individual variation. (6) In patients with cerebral field loss, both DPR and RTs are impaired in seemingly intact visual fields. (7) ARM patients show pronounced loss of dynamic performance far outside the macula.

[Supported by DFG grant STR 354/3-1 to HS.]

◆ **Synchronisation of discrete and periodic events in tapping**

W Wolf, M Sharikadze, K-D Cong, G Staude (Institut für Mathematik und Datenverarbeitung, Universität der Bundeswehr München EIT-1, Werner Heisenberg Weg 39, D 85577 Neubiberg, Germany; e-mail: werner.wolf@unibw-muenchen.de)

Tapping experiments are a commonly used technique to analyse the sensorimotor system, in particular timing effects. It is applied to healthy subjects (physiological case) and to patients (pathological case) in order to achieve new insights in basic research and to support diagnosis, respectively. A prominent topic in tapping research is how the production of a rhythmic sequence, either unimanually or bimanually, is achieved (central oscillator, sensorimotor feedback loop, etc). This study focuses on the coordination of a discrete tap within a periodic tapping sequence of the other hand. During the task execution, contact times, finger positions, and the

electromyogram (EMG) of the involved muscles were recorded. Results show different effects depending on the temporal relationship between the two motor tasks, especially in EMG and position signals which have not been usually recorded in previous experiments. These new effects are discussed under the viewpoint of the central timer hypothesis and as a consequence of the threshold-linear model including the motor periphery.

◆ **Neural substrates of joint attention: an ERP study**

B Zhou¶, S Han (Department of Psychology, Beijing University, 5 Yiheyuan Road, Beijing 100871, People's Republic of China [¶ also Generation Research Program, University of Munich, Prof.-Max-Lange-Platz 11, D 83646 Bad Tölz, Germany]; e-mail: zhou@grp.hwz.uni-muenchen.de)

Joint attention refers to the phenomenon that observers attention is attracted to the direction in which another individual is gazing. Previous studies showed that joint attention is reflexive, difficult to inhibit, and can effectively influence the early visual processing by shortening the latency and increasing the amplitude of P1 and N1 of visual evoked potentials. In the present study we further examined the difference between joint attention and the one triggered by a central moving item, as well as the role of face information. The results indicated that the behavioural consequences of these two attentions were similar. However, the modulation of early visual activity (P1) showed right-hemisphere dominance by joint attention, but not by the other attentional shift. The patterns of cortical modulation by these two attentions were similar with respect to N1, with the ipsilateral effect, indicating the different effects of joint attention at different processing stages. Furthermore, the right-hemisphere dominance in P1 weakened or even disappeared with the decrease of face information. The results indicate that joint attention is special; it influences the early visual processing (P1), with the right-hemisphere dominance; the face information is important for this specificity.

◆ **Contingent aftereffects—open questions with respect to spatiotemporal aspects of vision**

M Sharikadze¶, A Kezeli (Laboratory of Vision Physiology, I Beritashvili Institute of Physiology, Gotua 14, 0160 Tbilisi, Georgia [¶ also Institute of Medical Psychology, Ludwig Maximilians University, D 80336 Munich, Germany]; e-mail: msharikadze@yahoo.com)

For stable visual perception, stimulus identification should be independent of viewing conditions. Rigid perception of the visual world is guaranteed by the so-called compensative-correcting mechanisms of vision, which, operating subconsciously, make the necessary corrections (Kezeli et al, 1991 *Proceedings of the Georgian Academy of Sciences* 17 221–226). Such a mechanism of colour constancy, for example, supports, stable colour perception. However, sometimes these kind of corrections can result in illusory perception, as happens in the case of McCollough tape colour aftereffects (McCollough, 1965 *Science* 149 1115–1116), as well as in other contingent aftereffects, such as the angular-size illusion (Sharikadze et al, 2002 *Georgian Journal of Neuroscience* 1–2 59–64) and the double illusion [Malania et al, 2002 *European Journal of Physiology* 443 (Suppl. 2) S310 (abstract)]. The misperception takes place in ambiguous conditions, ie when information is ambiguous, incomplete, or superfluous, then contingencies between two features can be erroneously established. Spatial and temporal aspects of functioning of the compensative-correcting mechanisms, the influence of presentation times, and the duration of the illusory aftereffect are discussed.

BEHAVIOUR IN NATURAL ENVIRONMENT

◆ **The role of size in catching balls**

J Lopez-Moliner, D T Field¶, J P Wann (Departament de Psicologia Basica, GRNC Parc Científic de Barcelona, Universitat de Barcelona, passeig de la Vall d'Hebron 171, E 08035 Barcelona, Spain; ¶ Department of Psychology, Reading University, Whiteknights, Reading RG6 6AL, UK; e-mail: j.lopezmoliner@ub.edu)

How do we catch balls when practicing ball games? Although humans seem to do it effortlessly, a comprehensive account has not yet been proposed. The large variability and ambiguity undergone by the retinal image of the ball when it approaches the observer makes the use of retinal variables alone unacceptable for extracting the temporal information needed to guide our interceptive actions. Here, we tested whether the knowledge of physical size has an effect on the selection of optical information. We did so by interleaving catch trials (a size different from the expected one was used) in one experiment with two viewing conditions (monocular, and binocular plus monocular). The results show that, when the size of the approaching ball is known, observers switch to using a rate-of-expansion threshold to initiate the interceptive response. This strategy was not observed in a former phase where size was unknown. The same strategy seems to work when at least two sizes

are known. In sum, previous knowledge of the ball size, which can be obtained through different senses and experience, makes the required computations much simpler and enables observers to rely on a single optical variable, independently of the approaching trajectory.
[Supported by TINS2004-04363-C03-02.]

◆ **A representation of head-centric visual flow in human area pMST**

A V van den Berg, R S Menon¶, T Vilis§, S P Dukelow#, H H L M Goossens‡
(Department of Biology and Helmholtz Institute, Hugo R Kruijtgebouw, Padualaan 8,
NL 3584 CH Utrecht, The Netherlands; ¶ Advanced Imaging Laboratories,
John P Robarts Research Institute, London, Ontario N6A 5K8, Canada; § Department
of Physiology and Pharmacology [# Graduate Program in Neuroscience, Siebens-Drake
Research Institute], University of Western Ontario, London, Ontario N6A 5C1, Canada;
‡ Department of Biophysics, Radboud University Nijmegen Medical Centre,
NL 6500 HB Nijmegen, The Netherlands; e-mail: a.v.vandenberg@bio.uu.nl)

Little is known about the integration of visual and non-visual signals in human motion areas compared to monkeys. We used fMRI to test whether extraretinal eye-movement signals modulate responses to visual flow in the human MT+ complex. Following recent neuroimaging studies, we distinguished between pMT and pMST, and tested whether subdivisions of these areas may transform the retinal flow into head-centric flow. We report that interactions between eye signals and flow are not evenly distributed across MT+. Pursuit hardly influenced the response of pMT to flow while the responses in pMST to the same retinal stimuli were stronger during pursuit than during fixation. We also identified two subregions in which the flow-related responses were boosted significantly by pursuit, one overlapping part of pMST. In addition, we found evidence of a metric relation between rotational flow relative to the head and fMRI signals in a subregion of pMST. The latter findings provide an advance over single-cell recording studies in monkey MST. A visual representation of head rotation in the world derived from head-centric flow may supplement signals from semicircular canals, and is appropriate for cross-calibrating vestibular and visual signals.
[Supported by the Human Frontiers Science Program (grant SF0037/2000-B to HHLMG and grant RG96/34B to AVB, TV and RSM) and the Canadian Institutes of Health Research (SPD).]

◆ **Is visual search more efficient in dynamic environments?**

N E Scott-Samuel, P J Etchells, U Leonards (Department of Experimental Psychology,
University of Bristol, 12A Priory Road, Bristol BS8 1TU, UK;
e-mail: n.e.scott-samuel@bristol.ac.uk)

Most research into human visual-search behaviour has used static stimuli, or stimuli in which dynamic information differentiates targets from distractors, despite the fact that both the environment and its observers move. Subjects searched for a target Gabor patch, differentiated from the surrounding distractors solely by its carrier orientation, in three different types of array: static (stationary elements), jitter (oscillating elements), or dynamic (elements sequentially repositioned). Total orientation difference between target and distractors was varied between 5.7° and 22.6°, as was the number of elements in the display, and presence or absence of target. Search efficiency was defined by the gradient of the function of reaction time against set size. In target-present displays, search was efficient for all three array types, even at the smallest orientation difference. In target-absent displays, search efficiency was unaffected by the degree of target/distractor similarity in the dynamic condition, but decreased with increasing target/distractor similarity in the jitter and static conditions. This suggests that the visual system is better equipped to locate objects in dynamic environments, in contrast to static ones, and hence that much of the existing visual-search literature may fail to characterise human behaviour in natural environments.

◆ **Planning grasping-and-placing actions**

M P Aivar, J N Martín¶, E Brenner¶, J B J Smeets¶ (Departamento de Psicología Básica,
Universidad Autónoma de Madrid, Campus de Cantoblanco, E 28049 Madrid, Spain;
¶ Faculty of Human Movement Sciences, Vrije Universiteit, Van der Boechorststraat 9,
NL 1081 BT Amsterdam, The Netherlands; e-mail: mariapilar.aivar@uam.es)

Most of our daily actions consist of combinations of complex movements. Such actions could be planned as a whole, or split into separate movements that are each planned independently. Previous research with simple tasks and stimuli has shown that sequences of movements are sometimes planned together. Here we examine whether this is also true for a more complex task; one that is more representative of our daily actions. We examined the effect of the difficulty of a placing movement on the kinematics of the movement that involves grasping the object that is to be placed. Subjects were instructed to grasp a cube with their dominant hand and to place it either on a large wooden block (easy task) or on a narrow wooden cylinder (difficult task).

We found that the grasping movement took longer when the second movement was difficult (balancing the cube on the cylinder). The effect on the second, placing movement was much larger than that on the first, grasping movement, so the speed of the whole sequence of movements is not simply scaled. We conclude that planning subsequent movements influences the execution of earlier parts of an action.

[Supported by a grant from the EU].

◆ **The role of memorised location and peripheral visual information in making goal-directed movements**

A-M Brouwer, D C Knill (Center for Visual Science, University of Rochester, 275 Meliora Hall, Rochester, NY 14627, USA; e-mail: abrouwer@cvs.rochester.edu)

People can move their hands to a previously seen target with closed eyes by using the memorised location of the target. Is this information also used when visual information about the target is available? Using a virtual display, subjects sequentially picked up and moved two different 'magnetic' objects from a target region to a virtual trash bin with their index fingers. In one-third of the trials, we perturbed the position of the second object by one centimeter while the finger was transporting the first object to the trash. Subjects did not notice the perturbation. Although the second object was always visible in the periphery, subjects' movements were biased to its initial (remembered) position. The first part of subjects' movements was predictable from a weighted sum of the visible and remembered target positions, with weights of, respectively, 0.84 and 0.16. After approximately 60% of the movement, the contribution of memory started to decrease from 0.16 to 0.09. Diminishing the contrast of the objects to make them less visible in the periphery doubled the weight that subjects gave to the remembered location. Thus, remembered object location is used to plan goal-directed movements. Reliance on memory increases when the quality of visual information decreases.

◆ **Broader autistic phenotype, weak central coherence, and perceptual causality**

L E Grayson, A O Holcombe, J Briscoe ¶ (School of Psychology, Cardiff University, Tower Building, Park Place, Cardiff CF10 3AT, Wales, UK; ¶ Department of Experimental Psychology, Bristol University, 8 Woodland Road, Bristol BS8 1TN, UK; e-mail: GraysonL@cardiff.ac.uk)

Broader autistic phenotype (BAP) describes individuals with autistic-like characteristics including social and communicative difficulties. BAP has been related to 'weak central coherence', a failure to integrate local details into a global percept. This study related autistic-like traits [measured by the autism quotient (AQ) questionnaire] to perceptions of ambiguous stimuli. The stimuli depicted two balls of the same colour, the first passing over the (stationary) second ball in the ambiguous launch/pass baseline condition. In the experimental conditions, either a visual or auditory disambiguating cue presented at the point of the balls' spatial coincidence generally elicited a launch percept. The idea here was that weak central coherence would manifest itself in high AQ scorers (BAP group) as insensitivity to these contextual cues, such that they would not disambiguate the stimuli to the same degree as seen with low scorers. In the absence of cues, high AQ scorers ($N > 10$) perceived the ambiguous stimuli as causal more frequently than did the low-scoring group ($N > 10$). However, in the presence of cues, this pattern was reversed. Weak central coherence has historically been taken as a cognitive explanation for superiorities and deficits in autism, whereas here its origin would appear to be perceptual in nature, and possibly related to social behaviour difficulties.

[Supported by an Economic and Social Research Council (UK) Award to LG.]

◆ **The neural correlates of path perception and steering investigated with fMRI**

D T Field, R M Wilkie ¶, J P Wann (Department of Psychology, Reading University, Whiteknights, Reading RG6 6AL, UK; ¶ Institute of Psychological Sciences, University of Leeds, Leeds LS2 9TJ, UK; e-mail: d.t.field@reading.ac.uk)

In macaques, the ventral intraparietal area (VIP) contains optic-flow-sensitive neurons tuned for instantaneous heading direction. Initially, we confirmed similar function of the human VIP homologue in a task where participants made a continuous path judgment whilst viewing sinusoidal forward motion over a textured ground-plane. Additionally, we investigated the neural correlates of adding a roadway cue to ground-plane flow specifying future path. This produced a bilateral parietal activation focused on, but more extensive than, the (separately localised) lateral intraparietal area (LIP). Other cortical eye fields were not selectively activated by the roadway. In two further experiments, we investigated additional activation produced by adding an error signal between the road and the path travelled, or by participants actively steering. The anterior portion of the road-related parietal activation was more active when an error signal was present, whether due

to participant steering or when added by the computer during path judgments. Further activations for active steering that were not driven by the error signal were bilateral cerebellum, left dominant dorsal premotor cortex, and supplementary eye fields. These areas may be involved in the forward and inverse models necessary to map the steering device we used onto the simulated environment [Supported by EPSRC EP/D055342/1(P).]

SPATIOTEMPORAL VISION

◆ **Masking of Vernier stimuli reveals orientation-attractive effects suggesting spatial excitatory interactions between oriented filters**

T Tzvetanov, K Foltá (Cognitive Neuroscience Laboratory, German Primate Center, Kellnerweg 4, D 37077 Göttingen, Germany; e-mail: ttzvetanov@dpz.gwdg.de)

Visual misperception phenomena often shed light on neural mechanisms within the visual system. When a tilted grating is presented with a superimposed target line, subjects perceive a larger angular difference between the stimuli than physically present. This prominent misperception, called the repulsion effect of tilt illusion, is attributed to lateral inhibitory interactions between orientation-tuned neurons. Here, we investigated whether a tilted grating also influences the perception of alignment of superimposed and abutting line segments (ie Vernier stimuli). The results show that a visual misperception of the alignment is present, simultaneously with a misperception of line orientation. Intriguingly, the perceived orientations of the lines in the Vernier paradigm do not follow the standard repulsion of the tilt illusion. An opposite orientation-misperception effect (ie attraction) is observed, which strongly suggests that spatial excitatory interactions between orientation-tuned neurons are involved in the Vernier task, with the orientation tuning of these interactions being half as large as that of tilt repulsion. These results provide a new way to measure spatial excitatory interactions in addition to the well-known lateral spatial facilitation of contrast detection, and should lead to a better understanding of early contour integration in the human visual system.

◆ **The spatial layout and not the target – mask energy ratio determines backward masking**

M H Herzog, V Duangudom¶, G Francis§ (Laboratory of Psychophysics, Brain – Mind Institute, École Polytechnique Fédérale de Lausanne, CH 1015 Lausanne, Switzerland; ¶School of Electrical and Computer Engineering, Georgia Institute of Technology [Georgia Tech], Atlanta, GA 30332, USA; §Department of Psychological Sciences, Purdue University, West Lafayette, IN 47907-2081, USA; e-mail: michael.herzog@epfl.ch)

In backward masking, the visibility of a target is reduced by a following mask. Most research has focused on the phenomenon of B-type masking in which strongest masking occurs when the mask trails the target for about 30–80 ms. To account for this counter-intuitive result, all models of masking propose an inhibitory interaction between mask and target based on their energy ratio. Here, we present evidence from a metacontrast masking paradigm showing that the energy ratio does not by itself determine B-type masking. We presented a Vernier flanked by aligned Verniers. The strongest B-type masking occurred when the flanks had the same length as the Vernier. For longer (higher energy) and smaller (lower energy) flanks, performance improved. By further increasing the energy of the mask, we could even almost completely reduce masking. Hence, energy is not the key to explaining masking. We suggest that the overall spatial layout of the mask is a much better factor to explain backward masking in general.

◆ **Development of temporal contrast sensitivity in monkeys**

L Kiorpes, K A Stavros (Centre for Neural Science, New York University, 4 Washington Place, Room 809, New York, NY 10003, USA; e-mail: lynne@cns.nyu.edu)

Temporal vision, most basically the ability to detect variations in luminance over time, is essential for motion perception. Studies of temporal vision development in infants are few and the results are somewhat contradictory. In particular, some studies show early development of critical flicker fusion frequency compared to sensitivity to lower temporal frequencies (TFs). To learn more about temporal visual development, we measured temporal contrast sensitivity (TCS) in young macaque monkeys (*Macaca nemestrina*). We tested the ability of seven animals, ages 5 weeks to 4 years, to detect an unpatterned field of light whose luminance was sinusoidally modulated over time at a range of TF from 1 to 40 Hz; two monkeys were tested longitudinally. The results from the youngest infants showed reduced sensitivity for all TFs, and a reduced range of detectable TF. Sensitivity to all TFs appeared to develop at similar rates, although mid- to high-TF approached adult values somewhat earlier than low. Adult levels of temporal sensitivity were reached slightly earlier than spatial vision: by 6 months postnatal. These data suggest that the mechanisms limiting development of spatial and temporal contrast sensitivity mature at different rates, and that the TCS function changes shape during development.

[Supported by a Fight for Sight grant to KAS and NIH grant EY-05864 to LK.]

- ◆ **Supra-threshold apparent contrast and its dependence on the temporal autocorrelation function**
P J Bex, K Langley¶ (Institute of Ophthalmology, University College London, 11–43 Bath Street, London EC1V 9EL, UK; ¶ Department of Psychology, University College London, Gower Street, London, WC1E 6BT, UK; e-mail: p.bex@ucl.ac.uk)

While threshold contrast perception shows clear peaks in sensitivity, contrast constancy tends to normalise apparent contrast at supra-threshold levels. We used a stepwise paradigm to measure the shape of threshold and supra-threshold contrast sensitivity as a function of temporal frequency (TF) and presentation time. This paradigm shows that both threshold and supra-threshold contrast are inverted-U shaped as a function of TF at all contrasts. The tuning and the peak of the function varies with the conditions under which it is measured. Temporal contrast vision is low-pass at low luminances (1 cd m^{-2}) and brief durations ($< 200 \text{ ms}$), and band-pass at high luminances ($40\text{--}400 \text{ cd m}^{-2}$) and longer durations, owing to a loss in sensitivity at low TFs. The peak temporal frequencies of the band-pass functions increase with contrast and mean luminance. These findings are consistent with a transmission model in which the temporal autocorrelation function modulates visual sensitivity in two ways (i) via rapid gain control affecting low temporal frequencies, and (ii) by whitening the temporal tuning function.

[Supported by the Wellcome Trust.]

- ◆ **What is masked in masking?**

T U Otto, H Ögmen¶, M H Herzog (Laboratory of Psychophysics, Brain – Mind Institute, École Polytechnique Fédérale de Lausanne, CH 1015 Lausanne, Switzerland; ¶ Center for Neuro-Engineering and Cognitive Science, University of Houston, Houston, TX 77204, USA; e-mail: tom.otto@epfl.ch)

In visual masking, the visibility of a target can be strongly reduced by a following mask. Here, we show that even if the target is invisible, some of the features can be rendered visible. However, this visibility depends strongly on perceptual grouping. We presented a target Vernier followed by sequences of non-overlapping flanking lines that were successively shifted further away in space. A motion percept of two streams of lines was elicited. Even though observers were not able to detect the central target Vernier, surprisingly its offset can be perceived in the stream of lines. Moreover, the mislocalised Vernier offset can be combined with offsets of the lines in the stream. Whether or not features of two lines are integrated depends precisely on whether the Vernier and the lines are grouped to the same motion stream. We suggest that, because of this sensitivity to motion-induced grouping the visibility and attribution of features are not caused by limitations of the visual system, but are rather an active feat of the human brain.

[Supported by the Swiss National Science Foundation.]

- ◆ **Contrast sensitivity adaptation in a virtual spiking retina and its comparison with mammalian retinas**

A Wohrer, G Masson¶, L Perrinet¶, P Kornprobst, T Viéville (INRIA, Odyssee Team, 2004 route des Lucioles, BP 93, F 06902 Sophia-Antipolis, France; ¶ Dynamique de la Perception Visuelle et de l'Action (DyVA) – INCM (UMR 6193/CNRS), 31 chemin Joseph Aiguier, F 13402 Marseille Cedex 20, France; e-mail: adrien.wohrer@sophia.inria.fr)

Two important functional properties of biological retina, the nonlinear adaptations to contrast and to luminosity, have been studied, starting from a biologically plausible simulated spiking retina (Wohrer et al, 2006 *Proceedings of the International Conference on Neural Networks* in press), that is built considering the physiological connectivity of layers of cells in the primate retina and uses an underlying conductance-based neuron model. Contrast sensitivity adaptation is first studied. We review the different mechanisms of 'normalisation' used in classical computational models and discuss their biological basis. We then propose a conductance-based feedback model that we apply to both plexiform layers. The first feedback is from horizontal cells to receptors. It provides adaptation to local luminosity. The second feedback is from amacrine cells to bipolar cells, and we claim that this feedback successfully accounts for contrast gain control. We validate our model by comparing our simulations to the measurements made by Shapley and Victor in 1978 on cat ganglion cells. Simulations on natural images are also proposed, and prove the perceptual efficiency of our feedback model for contrast adaptation.

THE NATURE OF THE VISUAL CODE IN SENSORY COMPARISONS OVER TIME AND SPACE

- ◆ **Comparison at a distance**

M V Danilova, J D Mollon (Pavlov Institute of Physiology, Russian Academy of Sciences, nab. Makarova 6, 199034 St Petersburg, Russia; e-mail: dan@pavlov.infran.ru)

It is remarkable that observers can discriminate stimulus properties with similar precision whether the targets are juxtaposed or are 10° apart. We have shown this for spatial frequency,

contrast, orientation, and the two cardinal axes of colour space. All stimuli were presented on an imaginary circle of 5 deg diameter, centred on fixation (Danilova and Mollon, 2003 *Perception* **32** 395–414; 2006 *Vision Research* **46** 823–846). Precision holds even when the targets fall in opposite hemifields. Such discriminations are unlikely to depend on hard-wired comparator units that draw signals of opposite sign from the two arbitrary regions in which the targets fall. Too many dedicated comparators would be needed. It might be objected, however, that some pre-striate cells have large receptive fields, extending across the midline, and so might serve as the dedicated comparators. To test such suggestions, we have measured colour discrimination when the interior of our imaginary circle was occupied by a ‘radial Mondrian pattern’, whose sectors varied randomly in chromaticity along the same colour axis as the targets. Subjects still exhibited excellent discrimination of patches lying on opposite sides of the Mondrian. The results favour a representation that can travel freely on a cerebral bus.

[Supported by the Wellcome Trust 072684/Z/03/Z.]

◆ **The meaning of the basic psychophysical law and the description of visual scene**

V D Glezer (Laboratory of Vision Physiology, Pavlov Institute of Physiology, Russian Academy of Sciences, nab. Makarova 6, 199034 St Petersburg, Russia; e-mail: gau@infran.ru)

The Weber–Fechner law is really a basic psychophysical law as it applies to different sensory systems, but it is unclear what functions of the system it reflects. In psychophysical experiments length discrimination thresholds were measured when two lines, test and reference ones, were presented in the left and right hemifields. Psychometric functions were obtained for each hemisphere separately for the cases where the test line was above or below the reference line. When the test stimulus was presented above the reference stimulus, the length of the reference line was overestimated in the left hemisphere and underestimated in the right hemisphere. When the reference stimulus was presented above the test one, the reference length was overestimated in the right hemisphere and underestimated in the left hemisphere. The main result is that, when the stimuli are presented in fovea and in the pair of lines the test line is above, the differential threshold is calculated by left hemisphere, and when it is below by the right one. On the basis of the obtained data, a neural net was constructed which explains why the visual brain discriminates when the reference line is below or above the test one. It is related to the description of the scene.

[Supported by grant RFH 05-06-06085.]

◆ **What is compared in 2AFC?**

M J Morgan (Applied Vision Research Centre, City University, Northampton Square, London EC1V 0HB, UK; e-mail: m.morgan@city.ac.uk)

The classical temporal n AFC task must involve some kind of memory. So must the classification task sometimes called the Method of Single Stimulus (MSS) in which observers must report whether a single target is larger/smaller (or CW/ACW) than a remembered standard. I argue that the same kind of memory is involved in both n AFC and MSS. The former is a special case of MSS in which the observer codes each stimulus with respect to an internal standard, and chooses by the ‘Max’ rule the one that is most different. Evidence is reviewed.

[Supported by EPSRC.]

◆ **What is the nature of the memory that mediates visual memory tasks?**

D G Pelli, N J Majaj ¶ (Department of Psychology and Neural Science, [¶] Center for Neural Science) New York University, 6 Washington Place, New York, NY 10003, USA; e-mail: denis.pelli@nyu.edu)

The task is strictly visual. Show a row of objects. Take them away. Show them again, with one removed, leaving a gap. Ask the observer to select the object that belongs in the gap from a lower row which shows all the possibilities. Using a variety of objects (letters, digits, animal silhouettes) we find that the observer’s memory capacity depends mainly on the number of syllables in the names of the objects.

[Supported by National Institutes of Health R01EY4432.]

◆ **Stereopsis and relative size change dominance as target separation increases**

B J Gillam, P Marlow (School of Psychology, University of New South Wales, Sydney, NSW 2052, Australia; e-mail: b.gillam@unsw.edu.au)

Stereoscopic acuity is known to decline as two targets are increasingly separated. Performance is often found to depend on the disparity gradient (disparity relative to separation) rather than on disparity per se. We studied a different aspect of stereoscopic performance as a function of target separation—the degree to which stereo dominated relative size in determining perceived relative depth of the targets. In experiment 1 three relative sizes were used; equal, left 1.3 times

larger than right or vice versa. Four disparities were used consistent with left target closer and four with right target closer. Eye movements were not controlled. At separations of less than 0.5 deg stereopsis almost completely dominated whereas by 4 deg separation relative size almost completely dominated. Stereoscopic dominance of targets with the same disparity gradient dropped off strongly with separation indicating some other determining factor. In experiment 2 exposures were 200 ms with fixation controlled. Again, at small separations disparity, was highly dominant, while at separations of only 2 deg size was. In experiment 3 we showed that this strong stereo dominance was unchanged for all eccentricities (up to 2 deg) of the closest pair (0.5 deg). With either cue alone there was high accuracy at all separations. Results are discussed in relation to the properties of the two cues and related to other data on the effects of target separation on performance.

[Supported by the Australian Research Council DP0211698.]

MOTION FROM THE BOTTOM UP: FROM DETECTION TO COGNITION

◆ **Motion from the bottom up: from detection to cognition**

Q C Vuong, K S Pilz, L Chuang (Department of Cognitive and Computational Psychophysics, Max Planck Institute for Biological Cybernetics, Spemannstrasse 38, D 72076 Tübingen, Germany; e-mail: quoc.vuong@tuebingen.mpg.de)

Motion signals projected onto the retina serve many different yet essential behavioural functions: from quickly detecting objects and segmenting them from background clutter, to effectively navigating through a dynamic environment and recognising and interacting with objects populating that environment. Not surprisingly, computer scientists, psychologists, cognitive scientists, and neuroscientists alike have actively studied the perception and processing of visual motion. Until recently, the general approach has been to investigate mechanisms of motion perception relevant for specific purposes and typically focused at a specific level of processing, such as stimulus-driven or cognitively driven mechanisms. Although this approach has greatly extended our knowledge and appreciation of visual motion processing, it is less clear how motion information relates across these different levels. The purpose of this symposium is to bridge the gap between these levels of visual motion processing and foster discussion between researchers across the various levels.

◆ **Where is the sense in low-level motion?**

G Mather (Department of Psychology, University of Sussex, Falmer, Brighton BN1 9QH, UK; e-mail: g.mather@susx.ac.uk)

Perceptual representations of visual motion can be constructed in two ways: from responses in specialised motion sensors (low-level), or by tracking position changes in spatial features (high-level). Here, I concentrate on the properties of low-level sensors, and how they contribute to perceptual representations. Space-time plots, and corresponding spatiotemporal Fourier spectra, offer a useful framework for understanding the properties of motion sensors. The most widely accepted model is the energy model, which assumes that each motion sensor has a receptive field that is oriented in space-time. Such receptive fields have a limited spatial and temporal extent, as revealed in both physiological and psychophysical studies. A number of basic properties of motion sensors have been established psychophysically: their response does not depend on phase alignment between frequency components in the pattern (spatial features); directional signals can be reversed by reversing the contrast of the stimulus, or by brief blank intervals between animation frames; directional signals become unreliable at long inter-stimulus intervals. These sensor properties have been used to establish that motion sensors contribute to perceptual representations of rigid 2-D and 3-D motion, and articulated motion. It is still unclear how low-level and high-level responses are integrated.

◆ **Specificity for optic flow in human MT and MST**

A T Smith (Department of Psychology, Royal Holloway University of London, Egham TW20 0EX, UK; e-mail: a.t.smith@rhul.ac.uk)

Many neurons in macaque MSTd are sensitive to global flow, responding preferentially to expansion or rotation. Sensitivity to optic flow in human MT and MST was explored with an event-related fMRI adaptation paradigm at 3 T. On each trial, two brief random-dot kinematograms were presented sequentially with a gap of 2 s. The first stimulus (S1, 3 s) is expected to reduce the response to the second (S2, 1 s) if they activate a common neural population. In different trials, S1 and S2 contained either the same or different types of global motion. MT and MST were defined in separate experiments by the established criteria. In human MST, the compound response was smaller (indicating adaptation) when the two had the same flow structure than when they differed, suggesting specificity to global flow. Surprisingly, MT showed very similar flow specificity. In V1, which is expected to respond only to local dot motions, no flow

specificity was seen. Control experiments showed that the result cannot be attributed to adaptation of cells sensitive to local translation, nor to increased attention to S2 in the different condition. It is concluded that not only human MST, but also human MT, contains neurons that are selectively responsive to optic flow components.

[Supported by the Wellcome Trust.]

◆ **Optic flow and perceptual stability: Parsing retinal motion into self and object motion**

S K Rushton, P A Warren¶ (School of Psychology, Cardiff University, Tower Building, Park Place, Cardiff CF10 3AT, UK; ¶ Centre for Human Sciences, QinetiQ Ltd, Ively Road, Farnborough GU14 0LX, UK; e-mail: rushtonsk@cf.ac.uk)

The human brain has a well-documented sensitivity to 'optic flow'—the characteristic pattern of retinal motion that results from movement of the observer's eye through the environment (self-movement). It has been assumed that the primary reason the brain is sensitive to optic flow is to aid the guidance of locomotion. We have recently suggested (Rushton and Warren, 2005 *Current Biology* 15 R542–543) it may have another purpose: to aid the perceptual stabilisation of the visual scene during self-movement and so allow the identification of object movement within the scene. The hypothesis runs as follows: if the brain can identify components of retinal motion due to self-movement, it should be possible to 'parse' these components out. Any remaining retinal motion can then be attributed to movement of an object within the scene. We report the results of a number of studies that are compatible with this hypothesis.

◆ **The role of attentional tracking in motion perception**

A E Seiffert (Department of Psychology, Vanderbilt University, 111 21st Avenue South, Nashville, TN 37203, USA; e-mail: a.seiffert@vanderbilt.edu)

Motion perception involves more than the passive registration of dynamic stimuli. It often entails active tracking of objects with visual attention and anticipating future object positions. While maintaining the correspondence between the location of spatial attention and the location of a moving object, another representation of motion may be actively produced. This talk is a summary of psychophysical and neuroimaging investigations of this active motion mechanism and its interaction with low-level, passive motion mechanisms. Results show that motion perception of texture-based stimuli may be supported by an attentional tracking process that works by detecting changes in object position. Experiments demonstrate the spatial, temporal, and speed sensitivities of this motion mechanism and reveal its complementary role in motion perception. Neuroimaging experiments aimed at isolating brain regions involved in attentional tracking reveal selective activation in posterior parietal cortex, but not in visual cortex. In addition, direction-specific patterns of activity in retinotopic visual areas arising from luminance-based stimuli predicted patterns arising from texture-based stimuli that were attentionally tracked. Taken together, these observations support the notion that attentional tracking plays a unique role in generating and modifying motion perception.

◆ **Recognising objects-in-motion**

I M Thornton (Department of Psychology, University of Wales Swansea, Singleton Park, Swansea SA2 8PP, Wales, UK; e-mail: i.m.thornton@swansea.ac.uk)

Traditionally, studies of face and object recognition have been primarily concerned with static aspects of structure. However, many important objects, particularly biological objects, signal their presence, their identity, and their function/intention through motion. I review recent work, both from my laboratory and other groups, that has begun to explore dynamic aspects of recognition. What types of motion mechanisms can we use to recognise biological objects? Can characteristic motion of face or body signal identity? When an object is experienced in a particular dynamic context, for example as part of a routine action sequence, will this consistent change over time affect later recognition? Here I hope to answer these questions and also to raise the more general issue whether recognition studies should continue to use static stimuli when eye and brain clearly evolved to decode a dynamic world.

PSYCHOPHYSICAL, ELECTROPHYSIOLOGICAL, AND BRAIN IMAGING APPROACHES TO SEGMENTATION AND GROUPING IN SPACE AND TIME

◆ **Processing of symmetrical shapes in short-term visual memory**

J Ninio (Laboratoire de Physique Statistique, École Normale Supérieure, 24 rue Lhomond, F 75231 Paris Cedex 05, France; e-mail: jacques.ninio@lps.ens.fr)

The time to determine whether two images are identical or not increases with image complexity, by about 60 ms per bit. Above 12 bits, the 'same' reaction times (RTs) become significantly larger (Brunel and Ninio, 1996 *Cognitive Brain Research* 5 273–282). Here, twenty-five subjects compared

3×3 , 4×4 , or 5×5 random arrays of black or white quadrangles either identical, or differing by a single element, and related either by a translation or by a symmetry around a vertical axis. The same 12 bits threshold was found for the two types of tests. The RT variations were strikingly parallel, but downshifted in the symmetric case by about 730 ms for the 'same' condition, and 650 ms for the 'different' condition. The detection of symmetry violation was the fastest and the least error-prone on the middle column in the case of 3×3 images, and on the second and third columns in the case of 5×5 images. These results suggest that symmetry as well as repetition comparisons are initiated with the construction of a 9–12 bits representation of one of the two images. This construction, rather than the comparison itself, would be faster in the case of symmetric images.

◆ **A cortical network mediating perceptual organisation for temporally defined form**

L T Likova, C W Tyler (Smith-Kettlewell Eye Research Institute, 2318 Fillmore Street, San Francisco, CA 94115, USA; e-mail: lora@ski.org)

Figure/ground categorisation is a key factor for theories of perceptual organisation, shape, and object recognition. To study the categorisation process underlying figure–ground organisation, we used spatial form produced solely by temporal asynchronies in subregions of random-dot fields (temporally defined form). These stimuli were contrasted with uniformly synchronous null-stimuli, generating no form. The response throughout the brain was assessed by functional magnetic resonance imaging (fMRI). In experiment 1 figure/ground was generated by an asynchrony between a central region (figure) and its surroundings. In experiment 2, figure/ground organisation was eliminated by asynchronous segmentation into multiple equivalent stripes. In experiment 3 cue-invariance tests of experiments 1 and 2 were replicated in a novel paradigm of asynchronous unidirectional apparent motion of the visual noise. All experiments were done with equated test/null attention. Our data show dramatic reorganisation of the cortical activation pattern with the perceptual switch from figure/ground to non-figural segmentation. Consistent figure/ground-specific activation was seen only in V5/hMT+, while background-specific suppression occurred in V1/V2, but both were abolished by eliminating the figure/ground organisation in the multiple-stripes condition, when the activation shifted to higher retinotopic areas. These data identify V5/hMT+ as the source driving retinotopic suppression in the V1/V2 representations of the ground regions. This is the first demonstration in the human brain of figure–ground categorisation through top–down suppression from V5/hMT+ to the V1/V2 ground representation.

◆ **Region- and edge-based configural effects in texture segmentation**

C Casco, E Giora (Department of General Psychology, University of Padua, via Venezia 8, I 35131 Padua, Italy; e-mail: clara.casco@unipd.it)

Line texture analysis results in a rapid representation of the texture region and, where the output of local oriented filters changes, in the perception of a texture edge. It is well known that, in the presence of a high orientation contrast, the detection of an edge is easier when lines on either side of the edge are parallel (collinear) to the edge. We found that an edge located between a single stripe of the matrix and the remaining texture region is no longer discriminated when the collinear elements (Gabor patches) on one side of the edge are part of the texture-region with dominant orientation rather than part of the single stripe. Moreover, we found that overall orientation of the elements was perceived when the edge was not. These results, not predicted by edge-based segregation models, indicate that configural effects in the region occur earlier and may cancel those at the edge. To account for our findings, we suggest that the edge-segmentation process is biased by mechanisms that group iso-oriented collinear elements resulting from region-based analysis.

[Supported by MIUR 2003, 2005.]

◆ **Orientation texture bars along an edge of a texture are more salient when they are parallel to the edge: Evidence from change detection**

L Jingling, L Zhaoping (Department of Psychology, University College London, Gower Street, London WC1E 6BT, UK; e-mail: l.jingling@ucl.ac.uk)

Neurons in the primary visual cortex (V1) receive iso-orientation suppression and collinear facilitation from neighbouring neurons. Consequently, their responses to texture bars on the edge of an orientation texture are higher when the bars are parallel (rather than orthogonal) to the edge. We call these texture bars a collinear edge. Li (2002 *Trends in Cognitive Sciences* 6 9–16) proposed that V1 outputs create a bottom–up salience map. Accordingly, the collinear edge is predicted to be more salient. We used the change-detection paradigm to test this prediction, since changes are more detectable at salient locations (Wright, 2005 *Spatial Vision* 18 413–430). A foreground texture of coloured vertical or horizontal bars was sandwiched between two background

textures of bars orthogonal to the foreground bars, with the texture border parallel to either the foreground or background bars. Hence, the foreground or the background has the collinear edge. Subjects were asked to detect any colour change between two sequentially presented stimuli, occurring in either foreground or background bars. We found that changes were more easily detectable when they occurred in the texture region with the collinear edge, regardless of the orientations of the edge or the bars of the texture, confirming the V1 prediction.

[Supported by the Gatsby Charitable Foundation.]

◆ **Electrophysiological and psychophysical investigations of texture discrimination mechanisms**

A K Harauzov, Y E Shelepin, T Selchenkova, S V Pronin (Pavlov Institute of Physiology, Russian Academy of Sciences, nab. Makarova 6, 199034 St Petersburg, Russia; e-mail: haral@infran.ru)

We investigated the mechanisms underlying local and global texture processing. Textures were rectangular matrices composed of Gabor patches. Matrices differed by the number of Gabor patches with vertical or horizontal orientation relative to other orientations. The task was to identify the dominant orientation. The global statistics of the textures were calculated as the difference between the number of vertical and horizontal patches in the stimulus as a whole. The local statistics were calculated as the relative number of spatially collinear gratings. The accuracy of the participants was low for discriminating less organised textures and improved with the amount of vertically or horizontally oriented Gabor patches, while their reaction times decreased. The amplitude of the late positive component P3 with latency 400 ms increased linearly, and the magnitude of P2 wave with latency 260 ms decreased with the amount of equally oriented gratings. Negative wave N2 with latency 180 ms increased with the amount of equally oriented gratings in an S-like way. We propose that, in the given experimental conditions, two mechanisms are involved in discrimination of the textures: global (texture statistics) and local (degree of collinearity) processing. We believe that by recording VEPs one can separately investigate the activity of these two processes.

[Supported by RFBR 05-04-49032; RHSF 05-06-06085; RFBR 06-07-89137.]

◆ **fMRI localisation of the mechanisms underlying the incomplete patterns discrimination**

A Sevostyanov, V A Fokin, A K Harauzov¶, Y E Shelepin¶, S V Pronin¶, T Selchenkova¶ (Military Medical Academy, Lebedeva 6, 194044 St Petersburg, Russia; ¶Pavlov Institute of Physiology, Russian Academy of Sciences, nab. Makarova 6, 199034 St Petersburg, Russia; e-mail: asevnov@mail.wplu.net)

We used fMRI to localise mechanisms underlying pattern discrimination by humans. Patterns were two matrices composed of Gabor patches. They differed by the relative amount of Gabor patches with vertical or horizontal orientation among other patches with quasi-random orientation. The less organised matrices contained 24% of grating with equal orientation, whereas the more organised images contained 56% of vertically or horizontally oriented gratings. The subjects task was to discriminate the dominant orientation—vertical or horizontal. The BOLD signals were evoked by the rotation of the orientation of each element in the matrix. We analysed the difference between fMRI responses to matrices containing 24% and 56% of grating with equal orientation. Discrimination of less organised ie more difficult to recognise patterns evoked much stronger and broader activation of the cortex than discrimination of matrices with high content of equally oriented elements. That stronger activity for less organised images was found in occipital, parietal, and prefrontal lobes in the left and right hemispheres. The results of fMRI analysis were compared with VEP data obtained in the same pattern-discrimination task.

[Supported by RFBR 05-04-49032; RHSF 05-06-06085.]

◆ **Neural correlates of global form perception in autism**

S Baldassi, F Pei¶, G Procida, R Iglizzi¶, F Muratori¶, R Tancredi¶, G Cioni¶ (Department of Psychology, University of Florence, via dei San Niccolò 87, I 50125 Florence, Italy; ¶Department of Developmental Neuroscience, IRCCS Stella Maris, University of Pisa, via dei Giacinti 2, I 56018 Pisa, Italy; stefano@in.cnr.it)

We investigated, using visual evoked potentials (VEPs), how information from local features is combined into perceptual wholes in autistic children. We used alternations of coherently arranged Gabor patches to form textures or contours in stimuli with randomly oriented elements. Studies with normal observers identified specific harmonic components (1F and 3F) in the VEPs already present at 8 weeks of age in human infants for the textures and at 6 months for the contours. We collected VEPs in response to textures, contours, and in a control condition (alternation of 2 random patterns) from twenty-four autistic observers aged 4–17 years and from age-matched controls. Using a sweep procedure, we quantified the relative maturity of the texture response by measuring the minimum amount of organisation required to elicit the texture-specific component.

Thresholds were measured by varying the percentage of coherently oriented patches. Both groups exhibited a reliable response for the textures, but autistics had generally higher thresholds. However, autistics had significantly lower responses for contours. On the basis of these data we speculate that texture integration is intact, as it relies on earlier stages of processing than contour integration; the latter can be fully achieved only at later processing stages.

[Supported by the Cure Autism Now foundation and by the Smith-Kettlewell Eye Research Institute.]

◆ **Impaired motion detection in normal observers: inhibition or segmentation?**

C C Jayasuriya, M Milders, A Sahraie ¶ (School of Psychology [¶ Vision Research Laboratories], University of Aberdeen, Aberdeen AB24 2UB, Scotland, UK; e-mail: c.jayasuriya@abdn.ac.uk)

Detection of a brief episode of coherent motion, embedded in a global stream of incoherent motion, can fail if it occurs shortly after a local colour cue which is the signal to switch attention to the global stream. Essential for this effect to occur is the presence of irrelevant coherent motion episodes (distractors) prior to the cue. Earlier we proposed that this motion blindness results from inhibition of the distractors and a delay in releasing inhibition on appearance of the cue (Sahraie et al, 2001 *Vision Research* **41** 1613–1617). An alternative explanation is that the motion blindness effect is caused by difficulties distinguishing distractors from target motions. In the current study we addressed this issue by varying the stimulus onset asynchrony (SOA) between distractors and target. Previous research in visual search tasks and visual marking suggested that inhibition takes about 400 ms to develop and at shorter distractor–target SOAs performance would be relatively unaffected. Our results showed better detection of motion targets at 300 ms SOA between distractors and target than at 500 ms SOA, even though discrimination between distractors and target is easier in the latter condition. These findings strengthen the evidence that inhibition, and not segmentation, causes the motion-blindness effect.

◆ **New issue concerning allocation of visual attention to perceptually grouped objects**

M Albert, S Essid, T Ripoll (Laboratoire de Psychologie Cognitive, CNRS UMR 6146 – Université de Provence, Centre St Charles, Bât. 9, Case D, 3 place Victor Hugo, F 13331 Marseille Cedex 3, France; e-mail: albertm@up.univ-aix.fr)

When part of an object or a perceptual group is cued, the benefit of attention spreads from the cued location to the entire object or perceptual group. We investigated to which extent attention could be allocated flexibly to a set of grouped elements. To do so, we presented a visual display consisting of a 4×4 configuration of outline elements organised by colour and/or shape similarity. Following a cue at one element, participants had to detect a probe target that appeared in any of the other elements. An object-based effect was found: participants responded faster to probe appearing in an element that was grouped with the cued element. However, this effect varied according to grouping factors (level of similarity and proximity between grouped elements) and a factor related to the attentional mechanism (cue–target SOA). In contrast with classical theories of perception, which have assumed that grouping occurs preattentively and then constrains allocation of attention, our results suggest that attention can contribute to perceptual grouping by allocating in a dynamic way to locations that share common feature with the cued location. We discuss how our findings account for the relation between perceptual grouping and the attentional mechanism.

◆ **A new principle of perceptual grouping: Discontinuous continuity**

B Pinna (Dipartimento di Scienze dei Linguaggi, Università di Sassari, via Roma 151, I 07100, Sassari, Italy; e-mail: baingio@uniss.it)

Wertheimer in his pioneering study in 1923 introduced the problem of grouping. The question he answered was: how do individual elements create larger (Gestalt) wholes separated from others? In a set of classical experiments, he discovered several ‘grouping principles’. One of these, interesting for our purpose, is good continuation. My aim in this work is: (i) to introduce a new principle, called ‘discontinuous continuity’, based on a limiting case not considered by the Gestalt principles, ie discontinuities on the same continuous edge that elicit the formation of larger wholes ungrouped from others and that, on the basis of the good continuation factor, should group in a homogeneous integrated percept; (ii) to demonstrate, through psychophysical experiments, the independence of this new principle from the known Gestalt ones; (iii) to introduce a new set of perceptual problems, derived from the new principle, according to which ungrouped components are not only independent objects (as the grouping principles can solely state) but appear as ‘phenomenal properties’ of an amodally homogeneous whole. The former subsumes all the variations and attributes them to an emergent object that ‘causes’ the perceptual properties. The latter annuls the variations and is specified by those properties.

[Supported by Fondazione Banco di Sardegna, Alexander von Humboldt Foundation, PRIN ex 40% Cofin. es. 2005 (prot. 2005112805_002) and Fondo d’Ateneo (ex 60%).]

◆ Seeing texture figures before boundaries

E Giora, C Casco (Department of General Psychology, University of Padua, via Venezia 8, I 35131 Padua, Italy; e-mail: enrico.giora@unipd.it)

Our results show that we can perceive the texture figures before their boundaries, in contrast with the classical visual segmentation accounts. In fact, we found that the temporal thresholds for the discrimination of the overall orientation were much lower (16.2 ± 1.5 ms) than for the detection of the boundaries (64.3 ± 12.7 ms). At short exposures (< 20 ms), before the detection of the texture edges ($d' = 0.2$), the overall orientation of the texture region pops out (accuracy = 87%). This information alone makes the texture figure quite salient ($d' = 3.2$), but can lead to a strong response bias when used in the figure orientation discrimination. With such a task indeed, the accuracy is either at ceiling (87%) or far below chance (23%), depending on whether global (figure) and local (texture elements) orientation are the same or different. These results suggest that a holistic representation of a texture surface is a very fast operation, more precocious than its segmentation. [Supported by MIUR 2003, 2005.]

COGNITIVE INFLUENCE ON VISUAL TASKS

◆ Hemispheric asymmetries in categorical perception of colour

A Franklin, G V Drivonikou, I R L Davies (Department of Psychology, University of Surrey, Guildford GU2 5XH, UK; e-mail: a.franklin@surrey.ac.uk)

Categorical perception (CP) of colour is shown when discrimination of two colours that cross a category boundary (between-category) is faster and more accurate than discrimination of colours from the same colour category (within-category), even when chromatic stimulus separation sizes are equated. Gilbert et al (2006 *Proceedings of the National Academy of Sciences of the USA* **103** 489–494) found that colour CP across the blue–green boundary was lateralised in adults, with larger category effects for the left than the right hemisphere. Here, we explore these hemispheric asymmetries, testing blue–green and blue–purple boundaries, and testing both adults and infants. On a target detection task adults were faster at responding to a coloured target if it was presented on a between-category background than within-category, and the between-category advantage was greatest when the target was presented to the right than to the left visual field. Four-month old infants were also faster at responding to a coloured target when presented on a between-category background than within-category, and a hemispheric asymmetry in the category effect was found. The nature and development of colour CP is discussed.

◆ Beyond the prime-target congruency: Dissociable primacy and frequency effects in masked priming

A Sokolov, P Guardini ¶, M Pavlova § (Department of Psychiatry and ZNL Center for Neuroscience and Learning, University of Ulm Medical School, Leimgrubenweg 12, D 89075 Ulm, Germany; ¶ also Department of General Psychology, University of Padua, via Venezia 8, I 35131 Padua, Italy; § Cognitive and Social Developmental Neuroscience Unit, Children's Hospital and Institute of Medical Psychology and Behavioural Neurobiology, MEG-Center, University of Tübingen, D 72076 Tübingen, Germany; e-mail: alexander.sokolov@uni-ulm.de)

Theories of perceptual priming take account solely of within-trial events like prime-target congruency and temporal arrangement. In a series of masked-priming experiments we examined if the frequency and serial order of congruent and incongruent trials affect visual target identification. Participants pressed a respective key deciding whether or not a target square had gaps in its outline. In a trial, two other stimuli were presented prior to the target: either a congruent or incongruent prime (same/different square, respectively) and a mask (square with dotted outline). In between-subjects designs, we varied the frequency of congruent and incongruent trials in the series (1 : 1, 1 : 3, and 3 : 1) and serial order of presentation (either congruent or incongruent trials were more, or equally, likely to occur at the series outset). The results indicate (i) a reliable priming for equally frequent trials with standard randomisation; (ii) frequent congruent trials augment priming, while (iii) frequent incongruent trials abolish priming regardless of the serial order; (iv) both congruent and incongruent trials presented at the outset yield comparable priming with equally frequent trials and frequent congruent trials. The findings suggest that the primacy (serial order) and frequency effects on priming are dissociable and that both within-trial and between-trial neural processing modulate perceptual priming.

[Supported by Deutsche Forschungsgemeinschaft, grant SO 465/7.]

◆ Concealed visual associations in everyday language

O Y Orlov (Institute for Information Transmission Problems, Russian Academy of Sciences, Bolshoi Karetnyi 19, 127994 Moscow, Russia; e-mail: ochakovo@iitp.ru)

“Humans are very visual creatures. Our mentality is permeated with visual imagery: we ‘visualize’ an outcome, we ‘see’ a solution, we ‘outline’ a plan; we ‘speculate’, ‘imagine’ and ‘foresee’ etc.

This visual bias should not surprise us. All primates are very visual animals” [Smith, 2000 *Biology of Sensory Systems* (New York: John Wiley)]. Language, the cornerstone of human intellect, is a permanent addressing to the meaning of words, a kind of parallel reality, different from words themselves. This implies experience, common for both parties (eg in a dialogue). The abundance of ‘visual’ words in any language for description of mundane knowledge causes no surprise. The shortest (100-word) version of the Swadesh list includes nine ‘immediately visual’ terms (eye, see, white, black, red, yellow, green, star, moon), and some ‘close to’ ones (night, cloud, sun). Cone-mediated sharp vision, confined to photopic conditions, has led to associations between understanding, seeing, and illumination. Derivatives from ‘light’, ‘shine’, etc express a positive attitude and are accepted as sign of honour. Opposite meanings have lexemes bound to dark, turbid, obscure, etc. Lots of figurative constructions involve eye, sight, etc, significant in social contacts, as well as the face, the subject of extraordinary visual attention. Of special interest are ‘socially important’ words, derived from seeing, as having possibly ancient origin.

◆ **Cognitive control of antisaccades: Interference with concurrent short-term memory storage and mental arithmetic?**

W X Schneider, H Deubel (Department of Psychology, Ludwig Maximilians University, Leopoldstrasse 13, D 80802 Munich, Germany; e-mail: wxs@psy.uni-muenchen.de)

Capacity limitations exist at several levels of the brain. Visual-spatial short-term memory (STM) is limited in terms of number of objects that can be simultaneously maintained (storage limit). Certain cognitive control processes such as mental rotation cannot be executed concurrently with other control processes—a ‘bottleneck-type’ limit. We tested whether the control of an anti-saccade—implying the inhibition of an erroneous prosaccade—is also subject to a bottleneck-type limit and whether it interacts with storage limitations. The basic dual task paradigm consisted of an antisaccade that had to be performed in temporal overlap with a working memory task. In the first two experiments, an antisaccade had to be carried out during the retention interval of a either a Sternberg STM task or a visual-spatial STM task. Results show that the amount and complexity of information to be retained did not influence the number of erroneous prosaccades. The next two experiments used simple mental arithmetic performed in temporal overlap with an antisaccade task. The number of prosaccades increased with the complexity of the mental arithmetic operation. Thus, cognitive control of an antisaccade did not interact with STM storage but interacted with complexity and temporal overlap of mental arithmetic operations.

◆ **Categorisation of colour photographs by pigeons: Evidence of picture – object recognition**

U Aust, L Huber (Department for Neurobiology and Behavioral Sciences: Emerging Focus Biology of Cognition, University of Vienna, Althanstrasse 14, A 1090 Vienna, Austria; e-mail: ulrike.aust@univie.ac.at)

Success in tasks requiring categorisation of pictorial stimuli does not prove that a subject understands what the pictures stand for. The ability to achieve representational insight is by no means a trivial one because it exceeds mere detection of 2-D features present in both the pictorial images and their 3-D referents. So far, evidence for such an ability in non-human species is weak and inconclusive. Here, we report evidence of representational insight in pigeons. After being trained on pictures of incomplete human figures the birds responded significantly more to pictures of the previously missing parts than to nonrepresentative stimuli showing arbitrarily shaped patches of human skin. This suggests that they perceived the relation between the (incomplete) human figures depicted in the training stimuli and live human beings, and recognised the missing parts shown in the test as representations of real body parts. The relevance of various stimulus aspects (such as colour and orientation) for picture – object recognition was investigated in a series of subsequent tests.

◆ **Category learning from positive and negative pairwise relations**

R Hammer, T Hertz, D Weinshall, S Hochstein (Interdisciplinary Center for Neural Computation, School of Computer Sciences & Engineering, Life Sciences Institute, Edmond Safra Campus, Hebrew University, IL 91904 Jerusalem, Israel; e-mail: rubihammer@gmail.com)

We investigated human category learning of novel visual stimuli on the basis of either positive or negative equivalence constraints (when information is provided that two exemplars belong to the same or to different categories). Knowing that in natural contexts positive constraints are usually informative while negative constraints are rarely so, we suspected that participants would not use the two types of constraints in similar ways, even when the amount of information in the two types of constraints is identical and sufficient for perfect performance. We found that when participants were provided with highly informative positive constraints, categorisation performance was usually fast, good, and normally distributed. In contrast, participants provided

with highly informative negative constraints were divided, with some achieving even higher performance, and others significantly poorer. These results, together with those of a battery of controls, suggest that: (i) people use positive constraints more intuitively, although they fail to use them perfectly; (ii) the use of informative negative constraints enables a less natural, but potentially more accurate, categorisation strategy, which many participants failed to implement even in the current simplified setting.

[Supported by the Israel Science Foundation 'Center of Excellence' and US-Israel Binational Science Foundation (BSF).]

◆ **Visual-recognition processing in conditioned behavior**

K N Dudkin, I V Chueva (Pavlov Institute of Physiology, Russian Academy of Sciences, nab. Makarova 6, 199034 St Petersburg, Russia; e-mail: cognition@pavlov.infran.ru)

We argue that Pavlov's principles of higher nervous activity are quite fruitful even today in investigating the problems associated with current neurophysiological trends as, for instance, cognitive processes and awareness. Pavlov already used such modern notions as thinking, understanding, and his concept of the analysis and synthesis included complex sensory processing. Conditioned behaviour (classical and operant conditioning) includes visual recognition as one of the basic stages; its function is the best current interpretation and understanding of visual scenes and objects. Storing of the information necessary for it is realised by means of learning and is connected with two aspects of long-term memory: with forming, storage, and reproduction cognitive structures, and with selective increase in their biological significance. We studied visual-discrimination tasks in monkeys before and after any modification of conditioned stimuli. The results obtained demonstrate 'transfer of training' after transformations of conditioned stimuli. The invariance of recognition is due to the presence of common sensory properties of visual objects, which are selected during sensory processing and are retained after transformations. This means, that visual discrimination learning processes form in long-term memory certain demarcating features representing cognitive structures providing recognition and classification of visual objects.

◆ **What about background and context influences on ultra-rapid object categorisation?**

O Joubert, D Fize, G A Rousselet, M Fabre-Thorpe (Centre de Recherche Cerveau et Cognition, UMR 5549 (CNRS – Université Paul Sabatier Toulouse 3), Faculté de Médecine de Rangueil, F 31062 Toulouse Cedex 9, France; e-mail: olivier.joubert@cerco.ups-tlse.fr)

In object identification the influence of the background remains controversial. We have shown that objects such as 'animals' and scene contexts (man-made vs natural) are categorised at similar speeds suggesting possible interactions between scene and object representations. Here, we directly test for contextual influences on object categorisation using a rapid go/no-go visual categorisation task in which subjects have to quickly lift their finger when they see an animal target (among man-made objects). In a first experiment, animals or objects were randomly presented either in their natural context or on a uniform grey background in which object segmentation should be much easier. Stimuli were flashed for only 26 ms. Subjects' performance was very high (96% accuracy, 374 ms median RT), but, remarkably, no difference was found between the two conditions. In a second experiment, animals and objects were presented randomly with either man-made or natural contexts. A mild but significant impairment of performance was observed when animals were presented in a man-made (incongruent) context (vs natural congruent context) with a 15 ms mean RT increase and a 2% accuracy decrease. The influence of context is discussed in relation with the 'accumulation of evidence' theory (Perret et al, 1998 *Cognition* **67** 111–145).

[Supported by a grant from the French Government, CNRS, Université Paul Sabatier Toulouse 3.]

POSTER SESSION

SEGMENTATION AND GROUPING

◆ **Classification and segmentation of visual stimuli in a biophysically constrained neuronal model of the primary visual cortex: Combining the temporal population code with the dynamic regulation of dendritic integration**

S Roth, D Kiper, P F M J Verschure¶ (Institute of Neuroinformatics, University and ETH Zurich, Winterthurststrasse 190, CH 8057 Zurich, Switzerland; ¶ also ICREA and Department of Technology, University Pompeu Fabra, E 08002 Barcelona, Spain; e-mail: sro@ini.phys.ethz.ch)

On the basis of earlier work on the encoding of complex stimuli by cortical networks in a temporal population code (TPC) (Wyss et al, 2003 *Reviews in Neuroscience* **14** 21–33) we designed a neuronal model to classify visual stimuli in the presence of distractors. The TPC is based on the notion that dense lateral excitatory coupling in cortical networks transforms spatial

stimuli into a unique spatiotemporal pattern, which can be used for stimulus classification. Central to the TPC are transmission delays that are proportional to the distance between neurons. Any perturbation of the activity dynamics evoked by a target stimulus, for instance due to distractors, will lead to a different encoding and possible erroneous classification. This raises the question how we can retain the advantageous classification properties of the TPC while adding the capability to segment multiple stimuli. In previous work, we have shown that the modulation of dendritic attenuation can play such a role (Verschure and König, 1999 *Neural Computation* **11** 1113–1138). Here, we show that by including a more realistic biophysical dendritic model in combination with enhanced read-out properties, we are able to increase classification performance in the presence of distractors, thus achieving successful segmentation.

[Supported by ETHZ Grant 0-20214-04.]

◆ **Eye-movement recording for the comparison between different principles of grouping**

A I Fontes, S Fontes, A Villarino (Facultad de Psicología, Universidad Nacional de Educación a Distancia, Juan del Rosal 10, E 28040 Madrid, Spain; e-mail: aifontes@psi.uned.es)

We performed three experiments in which we monitored the eye movements of subjects as they performed a task of grouping. We composed the stimuli with Wertheimer's classic configurations. In experiment A we used the principle of good continuation; in experiment B that of proximity; and in experiment C that of similarity. Our goal was to compare these three principles of grouping. The data show that the necessary response time to complete the task is similar in experiments A and B, whereas in experiment C it is very long. There are few fixations in the similarity condition; more in the good continuation condition; and many more in the proximity condition. The largest fixation durations were in the similarity condition and there were no differences between the other two conditions. We interpret these results in terms of two factors: (i) the power of the stimulus characteristics to guide saccades, with similarity and relations of edges being powerful, and proximity being weak; and (ii) the major peripheral pre-processing and minor central-foveal processing that would explain the decrease in fixation duration when the grouping is for similarity.

◆ **Extrafoveal grouping by proximity in multistable dot lattices**

L Bleumers, P De Graef, K Verfaillie, J Wagemans (Laboratory of Experimental Psychology, University of Leuven, Tiensestraat 102, B 3000 Leuven, Belgium; e-mail: Lizzy.Bleumers@psy.kuleuven.be)

Grouping by proximity in multistable dot lattices centred on fixation is predicted by the Pure Distance Law (Kubovy et al, 1998 *Cognitive Psychology* **35** 71–98). The lattices can be grouped as a collection of parallel lines in four ways. The model assumes that the probability of making a certain organisation depends purely on the distance between the dots that are grouped together relative to the shortest possible interdot distance. We investigated whether the model still holds when the dot lattices are presented extrafoveally. We presented dot lattices within a circular aperture (radius 6 deg) either at fixation or on the right of fixation (left border at 3 deg or 15 deg). We varied the ratio of the second shortest to the shortest interdot distance (aspect ratio: 1.00; 1.08; 1.17; 1.26) and examined how this influenced the probabilities of choosing the corresponding organisations. Participants indicated the perceived organisation. Although grouping by proximity was influenced by aspect ratio, we found that the Pure Distance Law does not adequately describe it when the lattices are shown away from fixation. A possible explanation is that under these circumstances participants cannot always optimally attend to the lattice and respond randomly in a percentage of the trials.

[Supported by GOA/2005/03-TBA and FWO G.0095.03.]

◆ **Some grouping effects observed in perceptual fading**

D Yoshino, Y Sakaguchi (Institute of Information Sciences, College of Humanities and Sciences, Nihon University, 3-25-40, Sakurajosui, Setagaya-ku, Tokyo, Japan; e-mail: dyoshino@hi.is.uec.ac.jp)

We examined the nature of disappearance and re-appearance of target stimuli in perceptual fading, especially when multiple targets are placed nearby. In experiment 1, when an additional stimulus was presented near a perceptually faded object (a disk), the fading was instantly broken. When the object was physically removed after the object faded perceptually, on the other hand, it reappeared for an instant, and then disappeared. In experiment 2, we examined the effect of the same manipulations in the multiple target condition. The objects reappeared simultaneously also when an additional stimulus was presented nearby. Moreover, when they were physically removed, both faded objects reappeared for a moment and then disappeared. Therefore, when perceptual fading was simultaneously induced in nearby objects, they came back to our consciousness simultaneously as if they formed a group. On the other hand, when only one of the faded objects was physically

extinguished, the fading state of the other target was maintained while the extinguished object itself reappeared for an instant. This seems interesting because unlike the case of a physical transient stimulus, perceptual reappearance (or flash) caused by stimulus removal did not break the fading state. [Supported by the Nissan Science Foundation.]

◆ **Neural substrates for spatiotemporal grouping and perceived action in the human brain:**

Evidence from perceived writing sequence of Chinese characters

S-L Yeh, W-L Chou, S-Y Lin, D-Y Chen, J-H Chen, C-C Chen (Department of Psychology, National Taiwan University, Taipei, Taiwan; e-mail: suling@ntu.edu.tw)

Perceptual grouping by spatiotemporal congruency is important for perceiving continuous actions. We investigated neural substrates for processing perceived actions by measuring BOLD (blood-oxygenation-level-dependent) activation to Chinese character writing sequences. The block design fMRI had one test block containing characters presented stroke-by-stroke in generally accepted writing sequence (normal) and a control block containing characters with random stroke sequence. The BOLD activation ($N = 8$) was collected on a Bruker 3 T magnet (EPI, TR = 3 s, TE = 60 ms, flip angle = 90 deg). The lateral occipital complex (LOC) and the intraparietal sulcus (IPS) showed differential activation between normal and random writing sequence. The IPS activation was anterior to the areas responsible for saccade eye movement, while the LOC activation was in the dorsal part of the complex identified by contrasting pictures of objects and their scrambled versions. These results suggest that perceiving the normal writing sequence of a Chinese character by skilled readers involves not only perceptual organisation of each stroke in its right space and right timing but also action understanding similar to the one in the mirror-neuron system. [Supported by NSC93-2752-H-002-008-PAE and NSC94-2752-H-002-008-PAE.]

◆ **Information-theoretic interpretation of Gestalt**

A S Potapov (Department of Automatic Image Processing, Vavilov State Optical Institute, Birzhevaya linia 12, 199034 St Petersburg, Russia; e-mail: vist@rbcmil.ru)

The notion of Gestalt was developed in order to give a unified explanation for various phenomena of human perception and cognition. This aim has not been achieved owing to the approach being insufficiently strict. For the same reason, the Gestalt theory did not influence noticeably the field of computer vision. Nevertheless, it seems that the basic Gestalt principles are valid. Here, the Gestalt laws are consistent from the information-theoretic viewpoint. This implies that the perceptive field description having minimum length should be constructed. Proximity, similarity, good continuation, and other grouping laws are considered as an extraction of mutual information contained in the field elements (their features and positions). This formalism makes possible implementation of the grouping laws in computer programs. This is a positive result for computer vision. The information approach also resolves some difficulties of Gestalt psychology (conflicts between the grouping laws can be strictly resolved). A psychophysical experiment on visual grouping is being carried out in which the volunteers are to detect a given stimulus surrounded by random field elements. The detection probability appears to depend directly on the amount of information in the stimulus. It is planned to verify this result with more complex stimuli.

◆ **Piecemeal and holistic processing in perceiving and judging figural (im)possibility:**

An eye-movement analysis

G Shyi, H C Chen (Department of Psychology and Center for Research in Cognitive Science [¶] Department of Psychology, National Chung-Cheng University, 168 University Road, Min-Hsiung, Chiayi 621, Taiwan; e-mail: psycws@ccu.edu.tw)

Impossible figures have been used in arguments against holistic processing. That structural inconsistency is frequently missed when looking at impossible figures suggests piecemeal processing of these figures. It is not clear, however, whether piecemeal versus holistic processing represents dichotomous modes of processing or endpoints of a continuum varying in degree. One important factor may be the differences in attentional distribution. Here, we asked participants to judge whether a displayed figure was possible or impossible while their eye movements were monitored. The figures were depicted either as line drawings or as rendering via 3-D graphics. In experiments 1 and 2, participants were cued to attend to the whole figures. The results suggest that both possible and impossible figures were processed piecemeal when they were depicted as line drawings. Possible figures were processed holistically and impossible figures were processed piecemeal when both were 3-D rendered, however. In experiments 3 and 4, participants were cued to attend to different parts of the figures with varying sizes. The results suggest that both possible and impossible figures were processed piecemeal. The implications of differences in attentional distribution for piecemeal and holistic processing in perceiving and judging figural (im)possibility are discussed.

◆ **Studies of stimulus complexity in the Gollin test**

O A Vakhrameeva, A Y Mezentsev¶, S V Pronin§, Y E Shelepin§ (Biological and Soil Science Faculty, Department of Higher Nervous Activity [¶ Department of Physics] St Petersburg State University, 199034 St Petersburg; § Pavlov Institute of Physiology, Russian Academy of Sciences, nab. Makarova 6, 199034 St Petersburg, Russia; e-mail: wackys@mail.ru)

The relations between the recognition thresholds and size and complexity of the test images in the Gollin test were studied. Earlier we found that the Gollin figures differ in their complexity: the recognition thresholds of different stimuli vary from one stimulus to another. The ratio between the squared perimeter and the area of the test picture was used as an objective criterion of stimulus complexity. The subjective criterion for stimulus complexity was obtained by the following method. Naive volunteers had to differentiate Gollin test stimuli into three classes according to their complexity. The volunteers were not previously instructed what complexity implies, nor were they given any advice about the procedure. We compared their estimates of complexity with the previously measured recognition thresholds of different stimuli. There was no correlation between the recognition thresholds and stimulus complexity when the picture size was larger than the foveola. For the picture size of about 0.20 deg, positive correlation was found. We therefore propose to use the ratio between the squared perimeter and the area of the test picture as an objective coefficient of complexity. This coefficient allows us to differentiate Gollin test stimuli according to their complexity.

[Supported by the Russian Foundation for Basic Research (project 05-04-49032) and Russian Humanitarian Foundation for Basic Research (projects 05-06-06085 and 06-06-00252a).]

◆ **fMRI correlates of time-based figure – ground discrimination**

K Spang, M Fahle (Department of Human Neurobiology, University of Bremen, Argonnenstrasse 3, D 28211 Bremen, Germany; e-mail: kspang@uni-bremen.de)

Even purely temporal cues can induce figure – ground separation. Here, we compare the pattern of activation evoked by temporal figure – ground segregation with that evoked by motion-induced segregation. For the time-defined task, fifteen subjects saw a matrix of colons, each rotating around its imaginary midpoint, while lying in a 3 T scanner. Colons constituting the figure rotated in counterphase to those in the surround. In a control task, all colons jumped at the same time (homogeneous condition). For the motion task, all colons rotated continuously around their imaginary midpoint, with those constituting the figure rotating at a differing speed. Six subjects participated in this experiment. In all subjects, time-defined checkerboards produced significantly stronger BOLD responses than homogeneously jumping stimuli in all retinotopically organised occipital areas except most of V1. Moreover, several areas of the dorsal pathway were activated. Time-defined and speed-defined stimuli yielded virtually identical results. Our results thus provide further evidence for the notion that the human cortex contains mechanisms specifically designed to separate a figure from its surround on the basis of purely temporal information. Unlike contours defined by first-order contours such as luminance or colour contrast, these second order contours activate V1 far less than V2 and higher areas.

◆ **Detection of local symmetry as a function of additional regularities**

M Nucci Sr, J Wagemans¶ (Dipartimento di Psicologia Generale, University of Padua, 8 via Venezia, I 35131 Padua, Italy; ¶ Laboratory of Experimental Psychology, University of Leuven, Tiensestraat 102, B 3000 Leuven, Belgium; e-mail: massimo.nucci@unipd.it)

It has been shown that detection of symmetries which include other regularities is faster and more accurate than detection of simple symmetry. The aim of this study was to evaluate whether the presence of regularities that overlap with a local symmetry only partially also affects its detectability. We designed dot patterns consisting of 60 dots, using a cross-shaped matrix consisting of one central square and four external squares (above, below, left, and right), each square containing 12 dots. A local symmetry between the central square and one of the four external squares was defined as the target symmetry. Between the central square and the remaining three external squares additional repetitions or symmetries were imposed. Each of a large number of trials consisted of a short presentation of a new dot pattern, which subjects had to classify as symmetrical or not, with respect to the local target symmetry. Results show that the detectability of a local symmetry increased with additional repetitions in the neighbouring parts of the dot pattern, whereas a performance decrement was found when other local symmetries surrounded the local target symmetry. Results are discussed in terms of cooperation and competition between local regularities constituting global patterns.

◆ **Spontaneous and effortful mechanisms of perceptual organisation revealed by dissociation of evoked cortical activity**

A R Nikolaev[¶], S Gepshtein, M Kubovy[§], C van Leeuwen (Laboratory for Perceptual Dynamics, Riken Brain Science Institute, 2-1 Hirosawa, Wako-shi, Saitama 351-0198, Japan; [¶] also Institute of Higher Nervous Activity, Butlerova 5a, 117485 Moscow, Russia]; [§] Department of Psychology, PO Box 400400, University of Virginia, Charlottesville, VA, USA; nikolaev@brain.riken.jp)

Perceptual organisation is a semi-voluntary process. Here, we present neurophysiological evidence of a dissociation between the spontaneous and effortful aspects of perceptual organisation by taking advantage of the high temporal resolution of event-related potentials (ERPs). We asked observers to report perceived grouping in multistable dot lattices in which we varied the relative salience of competing organisations. We recorded the concurrent evoked cortical activity using a 256-channel EEG array. We found that observers' ability to discriminate the organisations (their grouping sensitivity) was positively correlated with the amplitude of the earliest ERP peak, C1 (55–80 ms after stimulus onset) over the primary visual cortex: the higher the amplitude, the greater the observers' sensitivity. Such early activity is attributed to spontaneous feedforward processing that precedes awareness. However, the observers' grouping sensitivity was negatively correlated with the amplitude of the next peak, P1 (110–120 ms), which is attributed to lateral and feedback interactions associated with conscious perception and attention. This dissociation implies that high grouping sensitivity depends on the early spontaneous mechanisms, whereas low grouping sensitivity depends on later mechanisms: The observers who fail to fully recruit fast spontaneous mechanisms try to compensate by using later less-efficient ones.

READING

◆ **No average reader: Professional readers employ a different fixational strategy**

I Lacis, R Paeglis, K Bagucka (Department of Optometry and Vision Science, University of Latvia, 8 Kengaraga, LV 1063 Riga, Latvia; e-mail: Ivars.Lacis@lu.lv)

Ability to read efficiently is an increasing challenge in the modern society. Poor reading practices are to blame for inadequate academic accomplishments of students. In eye-movement recordings, properties of fixations emerge as predictors of text comprehension and word skipping. We extend the concept of a skilled reader to a person whose professional duties consist of text analysis and reviewing. 'Reading professionals' demonstrated their fixational length and saccadic velocity pattern (iViewX). As compared to students of various fields, 'professionals' exhibited higher word-grouping selectivity and information retention. Their pattern cannot be extrapolated from the common skilled reading. To test the effect of educational practice, five 'non-professionals' were subjected to a speed-reading training for two months. After the training, the reading speed, number of fixations, and quality of text retention testified to higher processing efficiency. However, the reading pattern diverges from that of 'professionals'. We also stress that reading efficiency is language-specific. Fluent readers fixate about 60% more when reading in a second language, as compared to the native one. Eye movements in reading are specific to language and depend on education. Experimental data lend support to the conclusion that the concepts of 'average reader' and 'skilled reader' should be used with caution.

◆ **Chinese character recognition mediated by sub-morphemic component processing**

Y-C Chen, S-L Yeh (Department of Psychology, National Taiwan University, No. 1, Section 4, Roosevelt Road, Taipei 106, Taiwan; e-mail: r91227006@ntu.edu.tw)

Chinese characters correspond to monosyllabic morphemes; however, there is internal structure within each character. The majority contain a left (or top) semantic radical and a right (or bottom) phonetic stem, and radicals usually contain fewer strokes than stems. Previous studies showed reduced repetition blindness (RB) for radicals than for stems; however, it was confounded with the overall similarity at the character level. We examined whether the difference in RB was caused by the component properties or the overall similarity, by manipulating the relative proportion of a repeated component within a character. The conventional RB paradigm with rapid serial visual presentation (RSVP) sequence was adopted in experiment 1, and the two-frame presentation, similar to a priming paradigm, was used in experiment 2. Two factors—the type of repeated component (radical, stem, none) and its relative size (radical > stem, radical < stem)—were manipulated. Similar RB effects were obtained in both experiments. The smaller RB effect for radicals than for stems was replicated, and, most importantly, it did not interact with their relative size. These results suggest that Chinese character recognition is mediated by different processing of the two types of components rather than by the overall configuration at the character level.

[Supported by grants NSC93-2413-H-002-017 and NSC94-2752-H-002-008-PAE.]

◆ **Implicit knowledge of writing movements facilitates printed-letter recognition**

L Scocchia, N Stucchi, S Bouamama (Department of Psychology, University of Milano-Bicocca, piazza dell'Ateneo Nuovo 1, I 20126, Milan, Italy; e-mail: lisa.scocchia@unimib.it)

We investigated whether recognising a letter could be primed by the coincidence between fixation point and typical starting point of handwriting. Twenty-seven subjects performed both a writing pre-test (to assess where they began writing each uppercase letter of the alphabet) and a letter-recognition task. In the main experiment, standardised printed letters C, G, L, and U (3.53 cm × 4.59 cm) were presented next to the fixation point 10 times in each quadrant of the Cartesian plane. Letter presentation lasted 83 ms and was followed by a mask (14.12 cm × 18.36 cm) for 17 ms. Subjects were required to name the letters, and reaction times (RTs) were measured as the onsets of their verbal responses. If implicit motor knowledge facilitates letter recognition, greater accuracy and faster RTs would be expected in the third quadrant for C and G and in the fourth quadrant for L and U. A repeated-measures ANOVA and a Duncan a posteriori test were performed on accuracy. Reaction times were analysed first by computing ex-Gaussian parameter fitting for each letter, quadrant, and quadrant × letter interaction, and then running corrected Z-tests on the fitted parameters. Both analysis on accuracy and on reaction times confirmed predictions for C, L, and U.

◆ **Effects of prime and target eccentricity on masked repetition priming**

Y Marzouki, J Grainger (University of Provence – CNRS, Laboratoire de Psychologie Cognitive, 3 place Victor Hugo, F 13331 Marseille, France; e-mail: yousri.marzouki@up.univ-mrs.fr)

In two experiments we examined the influence of briefly presented, pattern-masked prime stimuli on target word recognition at varying eccentricities. Primes were either the same word as targets or a different word. In experiment 1, both prime and target position varied horizontally from a central fixation point. Target word recognition showed the typical effect of eccentricity with a distinct right visual field advantage, and priming effects were present in all but the extreme leftward position (-6°). In experiment 2, targets were always centrally located and prime position varied as in experiment 1. In these conditions, robust priming effects emerged only in the three most central positions (-2° , 0° , and $+2^\circ$). These data provide precise constraints on the limits of parafoveal processing of briefly presented words, and define the necessary spatial conditions for successful integration of information across prime and target stimuli in masked repetition priming.

◆ **Intensive short-term SLO reading training in subjects with central scotomas.**

Immediate functional benefits, gain retention, and adaptation of oculomotor strategies

A Deruaz, M Goldschmidt, A R Whatham, C Mermoud, E N Lorincz, A Schnider, A B Safran (Ophthalmology Clinic, Department of Clinical Neurosciences and Dermatology, Geneva University Hospitals, 22 Alide-Jentzer, CH 1211 Geneva 14, Switzerland; e-mail: anouk.deruaz@hcuge.ch)

We tested a training procedure aimed at optimising reading in patients with macular disorders. Two capacities—high spatial discrimination and global viewing of words—are essential to reading. In patients both are only occasionally achieved. We previously observed the fulfilling of these capacities by the combination of different eccentric fixation points. Five individuals were involved. All had previously undergone unsuccessful regular low-vision rehabilitation. We conducted ten 1 h training sessions, using scanning laser ophthalmoscopy. To fulfil the two capacities essential in reading, the patients were trained to read isolated words by combining the use of complementary eccentric retinal locations. Before, immediately after the training, and three months later, ETDRS acuity, threshold character size for words, and oculomotor strategies were assessed. A three-way repeated-measures ANOVA showed a significant main effect of the evaluation periods ($F_{2,19} = 46.04$, $p < 0.0005$). The a posteriori analysis with Bonferroni correction showed that all subjects benefited from the training procedure (before = 1.255 ± 0.017 , immediately after = 1.055 ± 0.016 ; $p < 0.0005$), and three months later (1.082 ± 0.014 , $p < 0.0005$). Subjects benefited differently from the training procedure and gains were retained differently as a function of word length. The analysis of oculomotor strategies supported these observations. Such training appeared beneficial to optimise reading strategies.

[Supported by the Pro Visu Foundation and the Fondation en Faveur des Aveugles.]

◆ **Visual noise in adults with specific reading disorder**

W Gibbons, P M Riddell (School of Psychology and Clinical Language Sciences, University of Reading, Earley Gate, Reading RG6 6AL, UK; e-mail: w.v.gibbons@rdg.ac.uk)

People with specific reading disorder (SRD) have a variety of visual problems, but these have only been indirectly related to the reading process. To show that visual system deficits are causally related to reading difficulties, we tested performance on a reading measure that stresses the

visual system directly. Stimuli were blocks of unrelated words in which letters were randomly rotated, or vertically spaced. The degree of internal visual noise during the reading process was estimated from the time taken to read words with increasing levels of distortion. The distortion level at which reading times begin to increase in a linear fashion provides a measure of internal noise (INM). Rotation INM scores were negatively correlated with reading ability, after accounting for non-verbal intelligence and baseline reading rate. For vertically spaced text, the correlation was not significant. These results suggest that adults with reading difficulties can be shown to have higher internal visual noise levels within the reading process than typical readers. The results for rotated and vertically spaced text suggest that the introduced noise affects different points in the reading process. These findings are discussed with respect to related fMRI activity.

[Supported by a PhD studentship awarded to WG by the UK Economic & Social Research Council (ESRC), under the supervision of P M Riddell.]

◆ **Influence of colour and attention in visual search and readability**

M L Fago de Mattiello, S Pescio, R Alvarez¶ (Secretaría de Investigación, Ciencia y Técnica, Facultad de Arquitectura, Diseño y Urbanismo [¶ Laboratorio de Investigaciones Visuales], Universidad de Buenos Aires, Ciudad Universitaria, Pabellón III, Núñez (1429), Buenos Aires, Argentina; e-mail: spescio@fibertel.com.ar)

It is well-known that readability of documents depends on contrast between text and background. Although achromatic documents have been the subject of frequent in-depth studies, it has become an issue owing to large-scale appearance of web pages in colour. Obviously, it is impossible to estimate readability of chromatic documents by using only the three visual factors of achromatic documents: letter size and style, contrast, and luminance of adaptation. For example, in the case of documents whose luminance contrast is 0.0, those with no colour difference between letters and background cannot be read, but those with enough colour contrast difference can be read in certain cases. This study deals with the subject by first establishing a measure of reference between achromatic and chromatic contrast before defining the equivalent luminance contrast of an achromatic document whose readability is equal to that of the chromatic document, and where the background luminance and letter size are equal. It then analyses the contribution of colour in the absence of differences in luminance. Finally, it proves the inhibitory effect of high luminosity backgrounds on texts of medium or low luminance, the effect of colour on luminance, and the select attention in visual search that enhances processing.

EYE MOVEMENTS, SACCADDES

◆ **Can dynamic actions of vergence be predicted from static fixation disparity?**

A Svede, O Nikitina (Department of Optometry and Vision Science, University of Latvia, Kengaraga 8, LV 1063 Riga, Latvia; e-mail: aigasv@lu.lv)

We analysed static and dynamic processes of vergence and their relationship, in order to discover whether fixation disparity can be used as indicator of asymmetry in the disparity-sensitive vergence mechanism. We looked for a correlation between static fixation disparity measurements and dynamic vergence movements in response to crossed or uncrossed disparity. The equipment used was the Eye-test-PC-system (Institut für Arbeitsphysiologie, Dortmund, Germany) which allows measurement of subjective dynamic changes of vergence at different times after presentation. We observed various responses to crossed and uncrossed disparity: subjects with quite good convergence and divergence responses; those with only convergence and no divergence responses; and those with only divergence and no convergence responses. We also had a subject with weak or even no convergence and divergence responses. These responses could be strong or weak. Subjects with good convergence and divergence can reach the appropriate degree of convergence almost within 1000 ms, exhibiting a latent period, and then a fast and a slow phase of vergence. Other subjects had a quite short fast phase of vergence, but a long slow phase, reaching only $\frac{1}{2}$ of the required vergence after 1000 ms. There seems to be no strong correlation between vergence response and fixation disparity.

◆ **Effects of a secondary spatial task on smooth pursuit eye tracking**

B Ulmann, D Kerzel (Department of Psychology, University of Geneva, 40 boulevard du Pont d'Arve, CH 1205 Geneva, Switzerland; e-mail: blandine.ulmann@pse.unige.ch)

Recent research has shown that attention is necessary to initiate and maintain smooth pursuit of a moving target. In two experiments, we investigated how smooth pursuit is affected by shifts of attention to briefly presented distractors. While a small red cross was pursued, Gabor patches (70 ms, diameter ~ 3 deg) were flashed that either induced retinal motion of their internal structure or not. In the control condition, subjects were asked to follow the smooth-pursuit target with their eyes while ignoring the distractor. In the experimental conditions, the flash was

presented during smooth pursuit and a secondary task had to be performed. In the first experiment, subjects had to hit the flash with their index finger. In the second experiment, subjects had to discriminate between different kinds of flashes (high or low spatial frequency of the Gabor patch). The results showed that the drop in pursuit gain induced by the flash was larger when the flash had to be attended to than when it was task-irrelevant. Also, the effect of the internal motion of the flash was more pronounced in the dual-task condition, suggesting that attention increases the gain of selected motion signals for smooth pursuit.

◆ **Eye-tracking study in pair comparison evaluation of objects design**

T Couronné§¶, A Guérin-Dugué¶, C Marendaz#, M Dubois‡, P Faye§ (§Laboratoire Perception et Facteurs Humains, PSA Peugeot Citroën, Route de Gisy, F 78943 Vélizy-Villacoublay, France; ¶Laboratoire des Images et Signaux, INPG, 46 av. Félix Viallet, F 38031 Grenoble, France; #Laboratoire de Psychologie et Neurocognition [‡Laboratoire de Psychologie Sociale], Université Pierre Mendès France, F 38040 Grenoble, France; e-mail: thomas.couronne@lis.inpg.fr)

We studied eye movements in the comparison of two manufactured objects which differed by visual signs that could have signal or semantic origin, in particular the relation between distribution of fixations and the evaluation of the two objects by subjects. We used the paradigm of pair comparison (Babcock, 2003, in *Proceedings of PICS 2003, Rochester, NY, 13 May* pp 10–15) to analyse processes of acquisition of visual information for each object. Our scene allows several levels of observation and interpretation. The pair comparison implies that the subject observes the scene with a strategy of exploration by selecting the area of interest in each object of the pair. The areas of interest are found by analysing the density of eye impacts and by comparing the distribution on each element of the pair. Finally, we studied statistical relations between the impacted visual zones, notations, and verbalisations with the aim of observing visual strategies and subjects' motivations. The results showed that there is a major correlation between the subjects' extracted look-zones, semiotic information, and evaluation.

◆ **Ocular torsion is a determinant of visual judgments of perceived orientation**

S C Goonetilleke, L E Mezey, A M Burgess, I S Curthoys (School of Psychology, University of Sydney, Sydney, NSW 2006, Australia; e-mail: sami@psych.usyd.edu.au)

Recently Poljac et al (2005 *Vision Research* 45 485–496) reported that the visual system compensates for ocular torsional position when making perceptual judgments. However, others have shown that ocular torsion is a determinant of perceived orientation (eg Wade and Curthoys, 1997 *Vision Research* 37 1071–1078). Here we show that a change in eye torsion does influence perceived orientation. We measured ocular torsional position using a video-oculographic system while subjects made allocentric judgments of a light bar to perceived visual horizontal using the method of adjustment with backtracking. The stimulus was a short line (20 deg) consisting of 5 LEDs at 30 cm viewing distance, presented either straight ahead or at eccentric gaze. The eccentric fixation positions (up to 20° upwards, and up to ±20° horizontally) induced changes in ocular torsion. There was a significant correlation between ocular torsion and visual perception, and we conclude that the visual system does not fully compensate for torsional eye position.

◆ **Searching again: Evidence for a memory recency effect in visual search**

C Körner, I D Gilchrist¶ (Department of Psychology, University of Graz, Universitätsplatz 2/III, A 8010 Graz, Austria; ¶Department of Experimental Psychology, University of Bristol, 12A Priory Road, Bristol BS8 1TU, UK; e-mail: christof.koerner@uni-graz.at)

Visual search often involves searching the same environment consecutively for different targets. We used a repeated-search paradigm and measured eye movements to study such search and to investigate if search benefits from previous exposure to the same display. In the experiment participants searched the same letter display twice consecutively for different targets. In each search the target could be either present or absent. To display onset simultaneously, a target was announced through loudspeakers (search 1). When the participant had made a present-absent manual response, a second target was announced (search 2). The location of the target in search 2 was kept constant relative to the last fixated item in search 1. Thus, the influence of target proximity on search performance was held constant, enabling us to assess the influence of visual short-term memory alone. Manual responses were faster for search 2 than search 1. Eye-movement recordings demonstrated that the time necessary to find a target letter depended on when that letter was last fixated in the previous search. This is a classical short-term memory recency effect. Search benefited from fixation recency up to about the last four fixations, indicating a limited-capacity short-term memory store in visual search.

[Supported by European Community (HPMF-CT-2000-00986), Wellcome Trust, Austrian Science Fund (FWF), grant P17458-G04.]

◆ **A comparison of bilateral versus unilateral target and distractor presentation in the remote-distractor paradigm**

V Benson, J M Findlay, S P Liversedge (Department of Psychology, University of Durham, South Road, Durham DH1 3LE, UK; e-mail: valerie.benson@durham.ac.uk)

Two experiments using the remote distractor effect (RDE) paradigm were designed to investigate RDE magnitudes for predictable and unpredictable target and distractor locations. Walker and colleagues have shown increased saccade onset latencies for bilateral target presentation compared to single target presentation. This bilateral target effect was uninfluenced by the pre-allocation of attention to one hemifield, and RDE magnitude is inversely proportional to distractor eccentricity. Mean RDE magnitudes were approximately 40 ms for central distractors, and 15 ms for peripheral distractors (Walker et al, 1997 *Journal of Neurophysiology* 78 1108–1119). We report data from two experiments that contrast with these findings. Under unilateral conditions, smaller RDE magnitudes occurred for peripheral than for central distractors, whereas under bilateral presentation conditions the pattern reversed. These data cannot be explained by simple differences between distractor and target size. They can be explained both in terms of discrimination processes associated with target identification under bilateral conditions and modulation of distractor salience by eccentricity under unilateral conditions. Alternatively, under bilateral conditions the RDE results from the time taken to suppress exogenously programmed saccades to the distractor, whereas under unilateral conditions endogenous saccades are exclusively generated.

◆ **The human saccadic adaptation field and space perception**

T Collins, K Doré-Mazars, M Lappe¶ (Laboratoire Cognition & Comportement, Paris Descartes University and CNRS, 71 avenue Édouard Vaillant, F 91774 Boulogne-Billancourt, France; ¶ Department of Psychology II, Westfälische-Wilhelms-Universität, Fliednerstrasse 21, D 48149 Münster, Germany; e-mail: therese.collins@univ-paris5.fr)

Saccadic adaptation is the progressive correction of artificial or pathologically induced systematic targeting errors. When a saccade of a given vector is adapted, vectors within a spatial window around the adapted vector are also affected. This adaptation field is well documented in monkeys but remains to be investigated in humans. Furthermore, saccadic adaptation affects the localisation of objects in space. We investigated adaptation-induced mislocalisation and examined whether it was structurally similar to the human saccadic adaptation field. The saccadic adaptation field was constructed by adapting a 12° saccade and testing transfer to 38 different saccades. The results show that the adaptation field is asymmetric around the adapted saccade. The effect of saccadic adaptation on spatial localisation was examined by asking subjects to localise a probe flashed before saccade onset by means of a mouse pointer just after saccade execution. Localisation judgments were shifted in the direction of saccadic adaptation. Adaptation affects both the metrics of eye movements directed to a position in space and the perception of that space. These results suggest that saccadic adaptation involves a recalibration of sensorimotor transformation, and that the system providing saccade metrics also contributes the metric used for the perception of space.

◆ **Holistic processing in saccadic control**

D Kerzel (Department of Psychology, University of Geneva, 40 blvd du Pont d'Arve, CH 1205 Geneva, Switzerland; e-mail: dirk.kerzel@pse.unige.ch)

In previous studies, manual classification of the vertical position of a visual target (up/down) was found to be slower when a simultaneously presented tone varied randomly in pitch (high/low: filtering condition) compared to a condition in which a tone of constant pitch was presented (baseline condition). The difference between filtering and baseline condition suggests that object perception depends on holistic processing in which it is impossible to perceptually separate the acoustic and visual dimensions of the object. The aim of the present study was to establish whether saccadic eye movements imply holistic processing of objects. Observers made saccades to visual targets above or below fixation. At the time of target presentation, a high-pitched or low-pitched tone was presented. In the filtering condition (variable pitch), saccadic latencies were longer than in the baseline condition (constant pitch). However, responses in the filtering condition were not faster when the position of the vertical target corresponded to the pitch of the tone (up–high, down–low). The findings are not fully consistent with recent ideas that goal-directed movements rely on analytic processing in which the response-relevant dimension is processed independently of other (irrelevant) perceptual dimensions of the object.

[Supported by the Swiss National Foundation 10011-107768/1.]

◆ **An extended perceived duration for multiple post-saccadic visual objects**

K Yarrow, P Haggard¶, J C Rothwell (Sobell Department of Motor Neuroscience and Movement Disorders, Institute of Neurology, University College London, 8–11 Queen Square, London WC1N 3BG, UK; ¶ Institute of Cognitive Neuroscience, University College London, 17 Queen Square, London WC1N 3AR, UK; e-mail: k.yarrow@ion.ucl.ac.uk)

Judgments about the duration and onset time of stimuli seen following a saccadic eye movement are biased. These biases suggest that the brain antedates the perceptual onset of a saccade target to around the time of saccade initiation. This mechanism could explain the apparent continuity of visual perception across eye movements. Previously, antedating was measured only for a single visual object, that was also the saccade target. We explored whether antedating extended to other visual objects seen peripherally following a saccade. Subjects made saccades to a target letter in a group of one, five, or nine letters. They judged the duration for which they saw one of these letters presented in an altered post-saccadic colour. Regardless of the number of letters in the display, or the presence of advance information about which letter would change colour, subjects overestimated letter durations compared to constant fixation control conditions. We conclude that multiple post-saccadic objects are subject to antedating biases.

◆ **Handedness influences eye movement behaviour**

V J Bourne, C Espiner, B W Tatler (Department of Psychology, University of Dundee, Perth Road, Dundee DD1 4HN, Scotland, UK; e-mail: v.bourne@dundee.ac.uk)

When looking at faces, there is a systematic bias to initially saccade to the left. This has been interpreted as being due to the typical right-hemisphere dominance for face processing. Is there a relationship between lateralisation and eye-movement behaviour? Here we examine the relationship between strength of handedness, a behavioural measure of lateralisation, and eye-movement behaviour when examining photographic scenes. A multivariate regression was run with the strength of handedness used to predict initial saccade direction, mean saccade amplitude, number of fixations on the left and right side of the image; and the fixation times on the left and right side of the image were recorded. The overall model showed a trend toward handedness predicting eye-movement behaviour ($F_{6,12} = 2.4$, $p = 0.097$). Handedness was a strong predictor of saccade amplitude ($\beta = -2.6$, $F_{1,17} = 11.7$, $p = 0.003$), explaining 37.2% of the variance. Individuals that are more strongly handed made smaller saccades. That handedness can account for such a high proportion of the variation in saccade amplitude clearly demonstrates a relationship between cerebral lateralisation and eye-movement behaviour. As such, models of eye-movement control ought to account for cerebral lateralisation.

◆ **Time-course of oculomotor inhibition revealed by saccade trajectory modulation**

E McSorley, P Haggard¶, R Walker§ (Department of Psychology, University of Reading, Reading RG1 6EJ, UK; ¶ Institute of Cognitive Neuroscience, Department of Psychology, University College London, 17 Queen Square, London WC1N 3AR, UK; § Department of Psychology, Royal Holloway University of London, Egham TW20 0EX, UK; e-mail: e.mcsorley@reading.ac.uk)

Selecting a stimulus as the target for a goal-directed movement involves inhibiting other competing possible responses. Both target and distractor stimuli activate populations of neurons in topographic oculomotor maps such as the superior colliculus. Local inhibitory interconnections between these populations ensure only one saccade target is selected. Suppressing saccades to distractors may additionally involve inhibiting corresponding map regions to bias the local competition. Behavioural evidence of these inhibitory processes comes from the effects of distractors on oculomotor and manual trajectories. Individual saccades may initially deviate either towards or away from a distractor, but the source of this variability has not been investigated. Here we investigated the relation between deviation and saccade latency. We used a fixation gap paradigm to manipulate latency independently of the influence of competing distractors. Targets were presented with or without simultaneous distractors, and the deviation of saccade trajectories caused by the presence of distractor was measured. Shorter-latency saccades deviated towards distractors and longer-latency saccades deviated away from distractors. The transition between deviation towards or away from distractors occurred at a saccade latency of around 200 ms. This shows that the time course of the presumed top-down inhibitory process involved in distractor suppression is relatively slow. [Supported by a grant from the Leverhulme Trust (awarded to RW and PH).]

◆ **Attention and programming of smooth-pursuit eye movements**

D Souto, D Kerzel (Department of Psychology, University of Geneva, 40 blvd du Pont d'Arve, CH 1205 Geneva, Switzerland; e-mail: david.souto@pse.unige.ch)

While recent studies indicate that the selection of saccade targets is preceded by a shift of attention to the target location, there is less evidence for the same coupling during the initiation

of smooth-pursuit eye movements (SPEM). Effects of attention shifts during SPEM programming were assessed in a Posner cueing paradigm. An exogenous cue indicated with 80% validity the location of a discrimination target (DT) at different delays before the motion onset. The DT was displayed 5 deg above or below the smooth-pursuit target. We observed improved discrimination performance in validly cued trials, indicating that observers were able to execute covert shifts of attention to peripheral DTs around the time of smooth-pursuit onset. However, the results also showed that SPEM onset was delayed for cues appearing around 100–200 ms before motion onset, regardless of whether the DT moved at the same speed as the pursuit target or remained stationary on the screen. We have thus identified the time interval in which attention has to be allocated to the pursuit target for efficient pursuit initiation to occur. The results argue for a strong coupling between attention and SPEM initiation, similar to what has been theorised about saccades. [Supported by the Swiss National Foundation 10011-107768/1.]

◆ **Visual attractors for eye movements in early vision**

O V Levashov, R A Rumyantseva (Moscow Pedagogical State University, Malaya Pirogovskaya 1, 119992 Moscow, Russia; olevashov@mail.ru)

Noton and Stark (1971 *Science* **171** 308–311) observed specific scan paths in viewing line drawings. We tried to trace the location of initial eye fixations using realistic colour images. A test image was presented for 500 ms and then was replaced by a marking image which had colour regions of small digits for coding the coordinates of the latest eye fixation. The task of the subject was to name the digit he/she saw. In subsequent trials the time of exposition was increased. The size of test image was 30 deg. The stimuli were 35 colour pictures—landscapes, pictures, and visual advertisements. Twenty-six adults participated in the experiment. No one subject has demonstrated any kind of scan-paths. Instead, the subjects noticed their attention to specific visual features—‘visual attractors’ (VA). These VAs were as follows: (i) high-contrast fragments, (ii) artificial textures, (iii) parts of human body, (iv) reflections in liquid surfaces, (v) familiar objects and distorted objects. Trajectories of eye scanning were not specified but traversed regularly 2–3 VAs. The results suggest that visual system has a collection of certain parallel filters for early extraction of ‘points of interest’.

◆ **Fixation locations when grasping occluded objects**

D D J de Grave, C Hesse¶, A-M Brouwer§, V H Franz¶ (Human Movement Sciences, Vrije Universiteit, Van der Boechorststraat 9, NL 1081 BT Amsterdam, The Netherlands; ¶Department for Experimental Psychology, Justus Liebig University Giessen, Otto-Behagel-Strasse 10F, D 35394 Giessen, Germany; §BCS, Center for Visual Science, University of Rochester, 275 Meliora Hall, Rochester, NY 14627, USA; e-mail: d.degrave@fbw.vu.nl)

When grasping objects with a precision grip and both contact positions of the digits visible, subjects look in the direction of the index finger (top of the object) or at the contact position that requires most accuracy (Brouwer et al, submitted). However, contact positions of the digits are not always visible owing to occlusion by other objects. Where do subjects fixate when one or both of these contact positions on the object are occluded by another object? Subjects were asked to grasp flat shapes with a precision grip at predefined contact positions (index finger on top and thumb at bottom of shape). Either the contact position of the thumb or that of the finger or both were occluded during grasping. The first saccades showed a general tendency to land near an intersection of the occluder and a visible part of the shape. When one digit was occluded, second saccades tended to go in the direction of the finger or to the digit that required more accuracy. When both digits were occluded, this tendency was only found when object information could be extrapolated. Thus an occluder affects fixation positions but it does not prevent fixating occluded object parts.

[Supported by a grant from the Deutsche Forschungsgemeinschaft (DFG: FR 2100/1-1) and by the European Research Training Network: Perception for Recognition and Action (PRA 623-00-099).]

◆ **Experimental estimation of comfortable target distance based on video-oculography method**

A G Yakushev, R R Kaspransky¶, G R Kaspranskaya§ (Applied Mechanics and Control Department, Mechanics and Mathematics Faculty, Moscow State University, Leninskie Gory, 119899 Moscow, Russia; ¶Y A Gagarin Cosmonaut Training Center, Star City, 141160 Moscow Region, Russia; §Sechenov Moscow Medical Academy, Bolshaya Pirogovskaya 2/6, 119881 Moscow, Russia; e-mail: moids@yandex.ru)

A hypothesis is presented with regard to the existence of a distance to a viewed target such that gaze fixation on the target is most comfortable for the observer. Theoretical calculations give this distance as about 0.95 m. To examine this hypothesis an experimental investigation was carried out in which video-oculography was used to evaluate the comfortable target distance. Five 15-mm-diameter balls were arranged in sagittal plane at the distances of 0.3, 0.6, 1.0, 2.0,

and 8.0 m from the eyes of the test subject. Microsaccadic eye movements for monocular and binocular target fixation were analysed by means of video-oculography. The biggest microsaccade amplitude was found for fixation on the 0.3 m target, then the amplitude decreased, reached a minimum at 1.0 m, and increased again from the 2 m target. This amplitude behaviour was clearly observed in both monocular and binocular records, but in binocular vision the amplitude was significantly greater than in monocular vision for all distances. It is postulated that the unimodal dependence of the amplitude on target distance originates from joint operation of the eye accommodative apparatus and extraocular vergent muscles.

◆ **Head movements modulate responsiveness to visual stimuli**

G M Cicchini, M Valsecchi¶, C de'Sperati§ (Department of Psychology, Università di Milano-Bicocca, piazza dell'Ateneo Nuovo 1, I 20126 Milan, Italy; ¶ Department of Cognitive Science and Education, Università di Trento, via Matteo del Ben 5, I 38068 Rovereto, Italy; § Visuomotor Functions Laboratory, Università Vita-Salute San Raffaele, via Olgettina 58, I 20132 Milan, Italy; e-mail: guido.cicchini@unimib.it)

While the strict association between visuospatial attention and saccadic eye movements is well documented, it is not known whether a similar association holds for head movements. As customarily both eye and head movements contribute to re-directing the gaze, we expect that making head movements would modulate responsiveness to visual stimuli. We measured the manual response time (RT) to a visual stimulus flashed when subjects pointed to a peripheral target with a saccade or with a fast head turn keeping the eyes on central fixation. The stimulus appeared in the same (compatible trials) or opposite (non-compatible trials) side of the movement, in the horizontal plane. The asynchrony between stimulus presentation and the onset of eye/head movement (SMA) was manipulated and varied between -400 ms (stimulus precedes movements) to 2000 ms. Compared to compatible trials, in non-compatible trials we found a mean RT increase of about 50 ms, which was larger for saccades than for head turns. The effect was observed already shortly before the beginning of the eye or head movement, and tended to disappear for large SMAs. Thus, programming head turns can create a transient unbalance of visuospatial attention, even when the gaze does not move.

◆ **Search experiments with blurred colour stimuli**

S Fomins, J Parkkinen¶, M Ozolinsh, V Karitans (Department of Optometry and Vision Science, University of Latvia, Kengaraga 8, LV 1063 Riga, Latvia; ¶ Department of Computer Science, University of Joensuu, Länsikatu 15, FI 80101 Joensuu, Finland; e-mail: sf00017@lanet.lv)

'C' letter optotype stimuli on white screen background were presented to observers with the task of finding a diagonally oriented gap letter between vertically oriented similar distractors. The stimuli presented consisted of the sum of the clear stimulus and the blurred contribution. Blurring was applied through digital filtering with a Gaussian. Michelson contrast ratio of the luminance modulation along the gap region was chosen as a measure of the blur depth. The stimuli subtended 0.37, 0.75, and 1.5 deg. Blue and green stimuli were presented to three observers and thirty trials were run for the each of the sets. The search time and the search object notification distance were analysed. Two distinct searching behaviours were found. In the case of the low-contrast and highly blurred sets the search behaviour is characterised by small step saccades mostly to the neighbouring distractor. Many backwards steps were made to compare the current stimulus with the previous one. With the high-contrast sets, more typical for blue stimuli, large rapid saccadic movements along the task field were dominant. The search behaviour characteristics were compared to the salience-based method of attention.

◆ **Trained to animals: Saccade differences to classify images**

R Paeglis, A Podniece, A Pikulins, I Lacis (Department of Optometry and Vision Science, University of Latvia, Kengaraga 8, LV 1063 Riga, Latvia; e-mail: roberts.paeglis@lu.lv)

Psychologists, neurobiologists, and computer vision experts agree that the human visual system can classify objects ultrarapidly. It does so even without foveating or paying attention. We explored saccadic parameters as image categorisation tools. The voluntary response of the observer comes from the oculomotor system that overlaps the perceptual system. Ten subjects were asked to make a saccade towards a peripheral image if it contained a target, or else make an antisaccade. The control is then not transferred to a different motor system, ie hand movement. Two synchronised computers with an iView X eye tracker were tuned to present a series of images for 300 ms each. With image recognition beyond 80%, eye movements as object recognition tools equip the researchers with additional knowledge about the classification process. Variability of saccadic velocities, amplitudes, and targets has been used as characteristics of image classification. We have studied regressive equations that describe gaze fixation 100 ms prior to the movement being launched.

Fixations and saccadic velocity are tightly bound to the features of the briefly presented stimulus. [Supported by the European Social Fund.]

◆ **Perceptual similarity between grey levels depends on learnt sensorimotor correlation between grey levels and eye movements**

A Bompas, M O Ernst ¶ (Max Planck Institute for Biological Cybernetics
[¶ Computational Psychophysics Department], Spemannstrasse 38, D 72076 Tübingen, Germany; e-mail: aline.bompas@tuebingen.mpg.de)

We propose that perceived similarity between two grey levels is related to the way they have been previously associated through eye saccades, actually reflecting their probability of co-occurrence in space and time. In the present study, we modified relative perceptual distances between grey levels by artificially associating certain pairs of grey levels with small eye saccades and other pairs with large eye saccades. In the test stage, we varied the luminance of a test patch (5 levels from 15 to 21 cd m⁻²) to determine the luminance perceived as 'right-in-between' that of two reference stimuli, dark and light (10 and 26 cd m⁻²). Each trial involved simultaneous presentation of one test grey and the two reference greys. The subject's task was to indicate whether the test patch looked more similar to the light or dark reference grey. Adaptation trials involved successive presentation of one of each test greys centred on the screen followed by the dark stimulus with a 10° eccentricity or the light stimulus with a 20° eccentricity, with equal probability. A control condition was employed without eccentricity difference. Only in the main condition does the post-test show an increased relative similarity between the test greys and the dark patch. [Supported by the Fyssen Fondation.]

◆ **Deficits of voluntary saccades in healthy aged subjects**

Z Kapoula, Q Yang (IRIS Group/LPPA UMR 7152, CNRS–Collège de France, 11 place
Marcelin Berthelot, F 75005 Paris, France; e-mail: zoi.kapoula@college-de-france.fr)

Healthy old subjects (aged 63–83 years) and younger adults (aged 20–32 years) were studied. Saccades were recorded in two tasks: (i) gap—the target appeared after a delay of 200 ms after the offset of the fixation point; (ii) overlap—the target appeared while the fixation point was still present; subjects needed to remove attention voluntarily from the fixation point. Eye movements were recorded with video oculography. Mean latencies of saccades (horizontal or vertical) were found to be significantly longer in the overlap than in the gap task for both young and old subjects. Latencies in aged subjects were longer than in young subjects for both tasks. Express latencies (80–120 ms) occurred more frequently in the gap condition; their rate was similar for young (25%) and elderly (21%) subjects. Thus, there is no age-modification in the hypothetical short retinal–collicular–brainstem circuit involved in express saccades. In contrast, the increase of latencies of regular saccades could be attributed to hypofunction of the parietal-frontal network involved in the triggering of such saccades. Elderly subjects may need more time to shift attention voluntarily. Thus, the gap/overlap allows us to identify a specific impairment in elderly subjects and suggests the existence of both non-aging and aging subsystems in the human CNS. [Supported by European Contract Eurokinesis, CNRS CTI/Handicap.]

NOISE, UNCERTAINTY, TEMPLATES

◆ **The effect of adaptation on signal and noise in the human visual system**

S Liebe, N K Logothetis, G Rainer (Department of Neurophysiology, Max Planck
Institute for Biological Cybernetics, Spemannstrasse 38, D 72076 Tübingen, Germany;
e-mail: sliebe@tuebingen.mpg.de)

Visual contrast adaptation decreases contrast sensitivity in visual detection. It has been suggested that decreased sensitivity is due to decreased signal output from visual elements tuned to the adapting stimulus properties, like spatial frequency. Alternatively, adaptation may decrease inhibition of the stimulus-analysing channel on other channels, or both phenomena may take place at the same time. Thus, adaptation may reduce the signal-to-noise ratio (SNR) of the tested visual capacity by affecting stimulus strength, noise, or both. We attempted to examine the origin of the experimentally observed reduction in the SNR of the contrast-detection mechanism. We used an external noise masking paradigm [Pelli, 1990, in *Vision: Coding and Efficiency* Ed. C Blakemore (Cambridge, Cambridge University Press) pp 3–24] to measure the relative contribution of SNR under various experimental conditions. Visual-detection contrast thresholds were measured twice at three noise levels through an adaptive staircase procedure. In one of two experimental blocks the observers were presented with an adapting stimulus for 25 s before the actual test stimulus (or a blank/noise field) appeared. As expected, detection thresholds increased linearly as a function of external noise contrast. Logarithm of thresholds increased uniformly as a function of adaptation irrespective of the logarithm of external noise contrast. The latter observation indicates that adaptation decreases SNR without affecting the noise of the detection mechanism.

◆ **Decision models in an uncertainty paradigm**

L A Olzak, J R Wagge, R D Thomas (Department of Psychology, Miami University of Ohio, Oxford, OH 45056, USA; e-mail: olzakla@muohio.edu)

The uncertainty paradigm is a rich source of information asking if two components or parts of a stimulus are processed independently or not. In this paradigm, observers discriminate between two patterns on the basis of differences in one of two potential cues. The cues may be contained in one of two components of a complex pattern or in one of two dimensions of a simple stimulus. In certainty conditions, the observer knows in which component or dimension the cue will be presented. In uncertainty conditions, the two cues are intermixed, and the observer does not know on any given trial which component or dimension contains the cue. Signal detection analyses of this paradigm demonstrate that a ratio of performance in the two conditions provides a measure of independence. A number of different underlying decision models can be assumed that lead to different quantitative predictions. We have previously presented results of one decision model that assumed independent decisions for the two components as well as equal variance, Gaussian noise. The model did not account for data obtained with orientation cues in the centre and surround of a bipartite field. Here, we explore the fits of additional models, including unequal noise.

[Supported by NEI EY13953 to LAO]

◆ **Characterising signal and noise in contrast detection by classification images**

I Kurki, A Hyvarinen, P I Laurinen (Department of Computer Science [HIIT] and Department of Psychology, University of Helsinki, PO Box 9, FIN 00014, Finland; e-mail: lmari.kurki@helsinki.fi)

Delectability of visual signals is dependent on two factors: efficiency of signal sampling and internal noise level. Various methods for estimating the relative contribution of these two exist, but often it is assumed that either the internal noise level or properties of the filters detecting the target stimulus are contrast invariant. To gain better understanding of both the signal sampling and internal noise, we estimated simultaneously the profiles of the perceptual filters and the internal noise level by using the classification image method with double-pass noise. Subjects performed a 2AFC detection task for a two-dimensional Gaussian bump (HWHM 1 deg) masked by white noise. Noise rms contrast was varied (2%, 5%, or 25%). Auditory feedback was used. Classification images show that filters estimated with high external noise are larger, and match the target profile slightly better, than filters estimated with low-contrast noise. Furthermore, absolute efficiency as well as internal noise level grows with the signal contrast.

◆ **Learning optimal features for visual recognition**

E Barth, U Siewert[¶], K Labusch, T Martinetz (Institute for Neuro- and Bioinformatics, University of Lübeck, Ratzeburger Allee 160, D 23538 Lübeck, Germany; [¶] PLANET intelligent systems GmbH, Residence Park 1-7, D 19065 Raben Steinfeld, Germany; e-mail: barth@inb.uni-luebeck.de)

The optimal-coding hypothesis (OCH) proposes that the human visual system has adapted to the statistical properties of the environment. We make three contributions related to this hypothesis. First, we discuss the criterion for optimality and show how the criteria of decorrelation (PCA), statistical independence (ICA), and sparseness are related to each other and to vector quantisation (VQ). Second, we propose to evaluate the different criteria by verifiable performance measures, eg the classification errors made by using the different features in a recognition task. Third, we believe that the usefulness of a criterion for optimality can be tested and better understood by applying it to data other than natural images. We analysed the classification performance on images of handwritten digits. The classifiers were using different sets of features obtained with different optimality criteria (PCA/ICA, sparseness). We conclude that the biologically motivated criterion of sparseness is very much related to more technical methods like the PCA/ICA and VQ. Nevertheless, it allows for some additional 'fine-tuning' from which recognition performance may benefit to a degree that is depending on the type of input data. While the OCH is appealing, the currently available mathematical methods of implementing it are related and limited.

◆ **Only one search template at a time**

R Houtkamp, P R Roelfsema[¶] (Department of Cognitive Biology, Otto von Guericke University, Haus 1, Leipzigerstrasse 44, D 39120 Magdeburg, Germany; [¶] Department of Vision and Cognition, Netherlands Ophthalmic Research Institute [KNAW], Meibergdreef 47, NL 1105 BA Amsterdam, The Netherlands; e-mail: Rozemarijn.Houtkamp@Nat.Uni-Magdeburg.de)

Selective attention facilitates the storage of the attended item in working memory. Vice versa, maintenance of an object in working memory biases selective attention towards that object in a

visual scene. Multiple items can be simultaneously maintained in working memory, and here we investigated whether more than one of such items can simultaneously support target detection. Participants were presented with a stream of coloured objects in a rapid serial visual presentation (RSVP) paradigm. They had to detect whether one of two pre-specified targets was present in the stream, and we contrasted performance on this two-target task with a situation in which there was only one target for search. Performance decreased significantly when there were two possible targets instead of one. This observed decrease in performance was so large that the subjects seemed only capable of using a single search template at a time. Remarkably, the decrease in performance occurred irrespective of whether the targets were from the same or from different feature dimensions. We conclude that only one representation in working memory can support a template-matching process.

◆ **The visual system exploits the contrast distribution in natural scenes**

H K Falkenberg, P J Bex (Institute of Ophthalmology, University College London, 11–43 Bath Street, London EC1V 9EL, UK; e-mail: h.falkenberg@ucl.ac.uk)

We used an equivalent noise paradigm to determine the effect of eccentricity and contrast distribution on the observer's ability to discriminate the direction of motion in natural scenes. Linear digital movies of the visual field at driving speeds of 50 km h⁻¹ were presented in forward or reverse sequence in different levels of space–time filtered noise whose spectrum matched the signal. The rms noise contrast was fixed; the rms movie contrast was under the control of a staircase. Observers identified the direction of motion of three natural movie conditions (standard, white, normalised contrast) and one 1/f noise condition. The white movie was created by spatially and temporally whitening the standard movie, and the normalised-contrast movie was the sum of 8 standard movies each rotated by 45° to normalise the distribution of contrast and features. Internal noise and sampling efficiency were estimated from the contrast-discrimination thresholds as a function of noise contrast. Internal noise did not change significantly across conditions or eccentricity. Sampling efficiency was highest foveally and for standard and white movies, and significantly lower for the normalised and noise movies. This suggests that motion sensitivity is critically affected by the leptokurtotic distribution of contrast in natural scenes.

[Supported by the Wellcome Trust.]

DEVELOPMENT AND AGEING

◆ **A cross-cultural investigation of colour preference development**

Y Ling, D Xiong¶, L P Cunningham, A C Hurlbert§ (School of Biology and Psychology [§ Institute of Neuroscience], University of Newcastle, Henry Wellcome Building, Framlington Place, Newcastle upon Tyne NE2 4HH, UK; ¶ Information Engineering School, Nanchang University, Nanchang, JiangXi 330029, China; e-mail: yazhu.ling@ncl.ac.uk)

Previously (Ling et al, 2004 *Perception* 33 Supplement, 45a), we reported robust cultural and sex differences in colour preference for British and Chinese adults (age range 18–24 years). Here we extend the study to school children (age range 8–9 years), and examine the development of colour preference across cultures. Observers (British: nineteen females, seventeen males; Chinese: twenty-eight females, twenty-four males) performed a paired comparison task for colour stimuli varying in hue, lightness, and saturation. The results illustrate robust sex differences in hue preference for British children, while the Chinese children show more individual variation, resulting in a less distinct pattern of hue preference on average, and no significant sex differences. All children exhibit preferences for brighter colours, with the preference stronger for females than males, for both British and Chinese. Comparing adults with children, the Chinese show an increase in preference weighting on the red–green axis (ie an increased preference for 'red'), while the British preference for 'red' decreases. For lightness, the Chinese preference for brighter colours increases with age, but the British preference for brighter colours decreases significantly. The differences in colour preference development between the British and Chinese demonstrate the importance of environmental and cultural influences on colour preference.

◆ **Development of the takete – maluma phenomenon: Children's performance on choice and visualisation task**

D Janković (Laboratory of Experimental Psychology, Department of Psychology, Belgrade University, Čika Ljubina 18–20, YU 11000 Belgrade, Serbia; e-mail: djankovi@f.bg.ac.yu)

In previous studies we evaluated the takete – maluma phenomenon and showed that the distribution of phonemes and consonant-vowel patterns in pseudo-names of abstract visual patterns depends strongly on some physical characteristics (sharp – oval, dark – light, etc) of the visual patterns (Janković and Marković, 2001 *Perception* 30 Supplement, 29). In this study we analysed the development of the takete – maluma phenomenon. In experiment 1, four groups of children

(aged 5, 8, 11, and 14 years) associated a set of generated pseudo-words (which varied in phoneme and consonant–vowel structure) with abstract visual patterns (which varied in angularity–curvilinearity, lightness–darkness, etc). The results showed that the phenomenon is confirmed at all age groups, including 5-year olds, and that it gets stronger with increasing age. In experiment 2, three groups of children (aged 7, 11, and 15 years) were asked to produce monochromatic abstract visual patterns corresponding to presented pseudo-words. 600 abstract visual patterns were produced. In phase 2, another group of subjects was asked to judge physical features of the visual patterns on bipolar scales (sharp–oval, dark–light, simple–complex, compact–disperse, and irregular–regular). The results showed that the most discriminatory dimension is sharp–oval, and that the phenomenon starts to appear in this kind of task after 7 years of age.

◆ **Perception of object integrity in infants: The evidence from smooth pursuit**

O Kochukhova (Department of Psychology, Uppsala University, Box 1225, S 75142 Uppsala, Sweden; e-mail: olga.kochukhova@psyk.uu.se)

Visual motion information is critical for our perception. Previous psychophysical studies (Beutter and Stone, 2000 *Visual Neuroscience* 17 139–153) provided evidence that both smooth pursuit and saccades are guided by visual processes related to perception and cognition. According to the study by Beutter and Stone (2000, loco cit.), in adults smooth pursuit can be used as an objective and continuous measure of the coherence of perceptual motion. The purpose of this study was to use such smooth-pursuit measurements in order to investigate integration of local motion signals into a global coherent motion pattern in infants. Smooth eye-movement responses of 5- and 9-month-old infants to line drawings of a parallelogram were investigated. The parallelogram was moved sinusoidally behind a stationary rectangular aperture. The apertures were constructed so that only the lines representing the sides of the parallelogram were visible; thus, recovering global motion of the parallelogram required integration of its segments. Two types of apertures were compared: a visible aperture, where perception of a coherent object was possible, and an invisible one, where only incoherent local motion could be observed. The results indicate that infants can perceive global motion of the object and can use this knowledge to control their eye movements.

◆ **Cognitive development and functional learning in a judgment visual task**

P Lafon, C Giraudeau¶ (Laboratoire de Psychologie ¶ Department of Psychology), Université François Rabelais, 3 rue des Tanneurs, BP 4103, F 37041 Tours Cedex 1, France; e-mail: lafon@univ-tours.fr)

We examined age-related differences in functional learning performances among children, adolescents, and young adults. Participants were asked to perform a visual judgment task involving two visual cues (coloured bars). The first cue was in direct relation and the second one was in an inverse relation with the event that was being judged (criterion). On each trial, participants were instructed to consider the visual values taken by two cues, predict from these cues the value of the criterion, and finally examine the corresponding feedback value. Our hypotheses were that: (a) very few children under 11 years of age would be able to learn how to use the inverse relation cue for predicting the criterion, although they would be able to correctly use the direct relation cue; (b) most participants over 17 years of age would be able to learn how to use the inverse relation cue and combine it with the direct-relation cue; and (c) adolescents between 11 and 17 years of age would show various levels of achievement. In general, these predictions were confirmed. Not until 11 years was a substantial proportion of participants (23%) able to reject the direct-relation hypothesis and select the inverse-relation hypothesis during learning.

◆ **Developmental dyslexia is a multifactor disorder: The neuropsychological approach**

R Bolzani, M Benassi, A Facchetti¶, A Finzi§, S Giovagnoli, K K Gummel#, S Vicari§ (Department of Psychology, University of Bologna, viale Berti Pichat 5, I 40127 Bologna, Italy; ¶ Department of Psychology, University of Padua, via Venezia 8, I 35131 Padua, Italy; § Ospedale “Bambino Gesù”, piazza Sant’Onofrio 4, I 00165 Rome, Italy; # Department of Ophthalmology, St Petersburg State Pediatric Medical Academy, 2 Litovskaya, St Petersburg, Russia; and Department of Clinical Neuroscience, Karolinska Institute, Bernadotte Laboratory, St Eriks Eye Hospital, Polhemsgatan 56, S 11282 Stockholm, Sweden; e-mail: roberto.bolzani@unibo.it)

Although increasing evidence from heterogeneous studies supports a neurobiological basis for developmental dyslexia, the underlying causes of this multisensory deficit are still unknown. The aim of this study was to understand better the relation between phonological awareness, perception of transient stimuli, visuo-spatial attention, and implicit learning. Thirty-one dyslexic children took part in this study. Phonological awareness was investigated with a verbal fluency test and a spoonerism task. Implicit learning strategies were evaluated with a modified serial

reaction time test, by measuring reaction time and the percentage of errors. Visuo-spatial attention was analysed with a test of everyday attention for children (TEA-Ch) subtest. A modified random-dot kinematogram test was used to study the perception of motion in different directions in terms of reaction time and accuracy. Significant correlations were found between phonological awareness, implicit learning strategies, and visuo-spatial attention tasks. Motion perception was found to be related only to visuo-spatial attention tasks. Two subtypes of dyslexia could be identified from the investigated abilities: in one subtype, the dysfunction affects the phonological system, implicit learning development, and visuo-spatial attention; whereas, in the other subtype, only motion perception and visuo-spatial attention are affected.

◆ **An investigation of cognitive dysmetria in developmental dyslexia**

L M Shanagher, M A Elliott (Department of Psychology, National University of Ireland Galway, Newcastle, Galway, Ireland; e-mail: louise.shanagher@nuigalway.ie)

An alternative to theories positing visual or phonological deficits, the 'cognitive dysmetria' hypothesis proposes the aetiology of dyslexia to take the form of a general functional coordination deficit or cognitive dysmetria. The term 'dysmetria' describes a general impairment in the temporal correlation of brain activity. The purpose of the current research was to investigate the empirical basis for this idea in an experimental task designed to measure simultaneity thresholds. Twenty children diagnosed with developmental dyslexia, alongside twenty age and IQ matched controls, undertook a series of threshold determination procedures designed to measure the location of simultaneity thresholds in time and the influence of subthreshold synchrony upon perceived simultaneity. The results are discussed with reference to local, visual impairments their relation to a more global dysmetria, and its potential implications for developmental dyslexia.

◆ **Infants' perception of a partly occluded object in an ambiguous motion display**

Y Otsuka, S Kanazawa¶, M K Yamaguchi (Department of Psychology, Chuo University, 742-1, Higashinakano, Hachioji-city, Tokyo 192-0393, Japan; ¶ Department of Psychology, Shukutoku University, Daiganji 200, Chiba 260-8701, Japan; e-mail: o2341004@crow.grad.tamacc.chuo-u.ac.jp)

McDermott et al (2001 *Perception* **30** 905–923) developed a diamond display, in which an outline diamond translated along a circular trajectory, its corners hidden by occluders. In this display, motion signals are locally ambiguous owing to the aperture problem. Nevertheless, adult observers generally perceive coherent motion of the moving diamond in this display. This perceptual bias is thought to depend on global completion of the occluded diamond. In our previous study, we found that 5–8-month olds but not 3–4-month olds perceived the coherent motion of the moving diamond in this display (Otsuka et al, 2005 *Perception* **34** 227). In the present study, we examined if infants could perceptually complete the diamond behind the occluders in McDermott's display. Infants aged 3–8 months familiarised with the McDermott's display and then were shown a complete diamond and a broken diamond side by side. Infants 5–8 months old looked longer at the broken diamond whereas infants 3–4 months old did not. These results suggest that 5–8 month olds could perceptually complete the diamond behind the occluders in the ambiguous motion display.

[Supported by RISTEX, Japan Science and Technology Agency, and by a Grant-in-Aid for scientific research (15500172) from the Japan Society for the Promotion of Science.]

◆ **Form perception of partly occluded shapes in infants**

T C J de Wit, S Vrins¶, P J N Dejonckheere§, R van Lier¶ (Department of Psychiatry, University Medical Centre St Radboud, PO Box 9101, NL 6500 HE Nijmegen, The Netherlands; ¶ Institute for Cognition and Information [NICI], Radboud University Nijmegen, PO Box 9104, NL 6500 HE Nijmegen, The Netherlands; § Department of Developmental, Personality and Social Psychology, Henri Dunantlaan 2, B 9000 Ghent, Belgium; e-mail: t.dewit@psy.umcn.nl)

Not much is known about the form that infants perceive when seeing partly occluded shapes. This becomes more relevant in the case of ambiguous shapes, where local and global cues may yield different completions. We conducted two habituation experiments to investigate how well-defined amodal completions are in 4-month-old infants. In the first experiment, we presented the infants with a simple, partly occluded shape until habituation was obtained. Then we showed either a plausible completion (one that would be predicted by both global and local theories) or an implausible completion. Longer looking times were found for the implausibly completed shapes (compared to plausible and control condition), reflecting a novel impression to the infants aged 4 months. In the second experiment, infants were habituated to more ambiguous partly occluded shapes where local and global cues would result in different completions. For adults, the percept

of these shapes is usually dominated by global influences. However, after habituation the infants looked longer at the globally completed shapes (again compared to local and control condition). By the age of 4 months, infants thus already have a clear percept of the form of partly occluded shapes, but, with more ambiguous shapes, completions seem to be dominated by more local influences. [Supported by the Niels Stensen Foundation.]

◆ **The 3/4 view effect in infancy—Behavioral and neuroscience data**

E Nakato, S Kanazawa¶, M K Yamaguchi§ (Department of Psychology, Komazawa University, 1-23-1 Komazawa, Setagaya-ku, Tokyo 154-8525, Japan; ¶ Department of Psychology, Shukutoku University, Tokyo, Japan; § Department of Psychology, Faculty of Literature, Chuo University, 742-1, Higashinakano, Hachioji-city, Tokyo 192-0393, Japan; e-mail: enakato@komazawa-u.ac.jp)

Our previous study (Nakato et al, 2005 *Perception* 34 Supplement, 167) showed that the rotation information promoted face recognition of 3/4 view in infants 6 to 8 months old. In this study, we investigated whether this rotation information would be effective for recognition of the profile view in infants around these ages. For familiarisation, we used 11 different face views of an unfamiliar female taken at different angles in steps of 9° from the frontal view to the left-side profile. Infants were familiarised with these views either in regular frame order (the rotation condition) or in random frame order (the random condition) for a total 80 s. Each image was presented for 260 ms. Following familiarisation, infants were shown a pair of static right profiles of familiar and novel females for 10 s each. Results suggest that the rotation information did not promote recognition of the profile view in infants. The rotation information might contribute only to the recognition of a novel 3/4 view. We also measured these infants' brain activity by near-infrared spectroscopy. We compared infants' brain activity on perceiving frontal view and side view of the faces. We present behavioural and neuroscience data on face recognition by infants.

[Supported by RISTEX, Japan Science and Technology Agency, and a Grant-in-Aid for scientific research (15500172) from the Japan Society for the Promotion of Science.]

◆ **Anticipative motion tracking in very preterm (< 32 weeks) infants measured at 2 and 4 months of corrected age**

C von Hofsten, K Rosander (Department of Psychology, Uppsala University, Box 1225, S 75142 Uppsala, Sweden; e-mail: claes.von.hofsten@psyk.uu.se)

In human infants the ability to smoothly pursue a moving object develops rather rapidly between 6 and 15 weeks of age. It has been shown in 1998 by Langaas et al that children born preterm (< 32 weeks) often have reduced gain in smooth pursuit at 5 years of age. The purpose of our study was to measure eye movements in young infants born before week 32. This longitudinal study includes infants born without malformations at a gestational age < 32 weeks. So far twenty-five infants have been studied. The measurements of eye movements were performed at 2 and 4 months corrected age when the infants were tracking a moving object. At each occasion the eye movements were measured with EOG and head/object movements with an optoelectronic system. As compared to controls, the gain of smooth pursuit was significantly lower at 2 and 4 months of age, although some (five of twenty-five) infants showed values similar to controls. Furthermore, at 4 months of age the lag of smooth eye movement relative to the head slip was lower than in controls by a factor of 2 to 3.

◆ **The effect of viewpoint observation on the body turn of another person in children**

M Noda (Department of Psychology, Edogawa University Health and Welfare Technical College, Komaki 474, Nagareyama-shi, Chiba 270-0198, Japan; e-mail: gbg00205@nifty.ne.jp)

Little attention has been given to the frontal plane of imagery transformation of another man's viewpoint. One hundred and eight children aged 4 years to 6 years were examined for the observation effect of imagery transformation with three conditions (2-point, 4-point, figure condition) and three age groups. Within this we examined the 80 non-observation data (partially reported in Noda, 2005 *Perception* 34 Supplement, 226). In this experiment children went through the same view of the astronaut's doll by the LCD, and examined whether the changing appearance according to the body inclination had an effect on the body rotation task (BRT) transformation. The correct response was defined as the right angle and orientation dimension. Correct responses increased with age, but no difference was found among the conditions. When the present observation group was compared with the previous non-observation group, there were differences. The non-observation group decreased with age, and although the two groups did not show a difference with the 4-year-olds, they did so with the 5- and 6-year-olds. This suggests that the

observation had a reverse effect on the 4-year-olds, but it might have caused redescription of the representation [Kamiroff-Smith, 1966 *Beyond Modularity* (Cambridge, MA: MIT Press)] based on the observation of the 5- and 6-year-olds.

◆ **Motion perception in Russian children with fetal alcohol syndrome**

K K Gummel, J Ygge¶, R Bolzani§, V V Brzhesky#, S Giovagnoli§, M Benassi§, A Zaychik‡ (Department of Ophthalmology, St Petersburg State Pediatric Medical Academy, Litovskaya 2, 194100 St Petersburg, Russia; and Department of Clinical Neuroscience [¶] Section of Ophthalmology and Vision Science], Karolinska Institute, Bernadottelaboratoriet, St Eriks Eye Hospital, Polhemsgatan 50/56, S 11282 Stockholm, Sweden; § Department of Psychology, University of Bologna, 5 Berti Pichat, I 40127 Bologna, Italy; # Department of Ophthalmology, St Petersburg State Pediatric Medical Academy, Litovskaya 2, 194100 St Petersburg, Russia; ‡ Research Institute of Endocrinology, Medical Academy of Postgraduate Study, Kirochnaya 41, 195257 St Petersburg, Russia; e-mail: simple.kristina@mail.ru)

60% of fetal alcohol syndrome (FAS) children have visual impairments. Investigations of visual functions by traditional methods do not appear to fully outline the problems these children may have. We therefore evaluated motion perception in FAS children. We investigated forty-nine children aged 10–16 years with verified FAS and fifty-two matched controls. We used computer-based motion detection test based on random-dot kinematograms consisting of 150 or fewer moving (in one of eight directions) white dots on a black screen. The stimuli were presented in two different sequences: sequentially (experiment 1) with increasing difficulty, and random (experiment 2). FAS children showed significantly lower performance at all noise levels in both tests, but the experiment showed significant differences between the two groups only in experiment 1. There was no difference in motion perception in random conditions, suggesting that random sequence is less efficient in discriminating the two groups. Results indicate that the magnocellular pathway, here appropriate for its testing, is impaired in FAS children. Strong differences found in our experiment with black-and-white normal sequence suggest that motion-perception stimulus is an efficient test to investigate perceptual performance and to discriminate the two groups. This may have implications for other visual functions such as reading.

◆ **Low score of visual successive recognition in children with dyslexia**

O V Levashov, J A Guziy, O B Inshakova (Moscow Pedagogical State University, Malaya Pirogovskaya 1, 119992 Moscow, Russia; e-mail: olevashov@mail.ru)

A weakness of the magnocellular system (MS) is considered to be an important factor in dyslexia. We used a modification of backward masking to compare effectiveness of MSs in good and bad readers. Stimuli were pairs of similar line drawings (familiar objects) and a cross/square pair. The stimuli were presented successively at 100 ms with an interval of 100 ms. Then a stationary mask (a superposition of 1st and 2nd stimuli) was presented. The subjects' task was to indicate which stimulus was presented first. Fifty-seven subjects (aged 7 years) with a different level of reading skill participated in the experiment. Good readers had no problems in this procedure. But we found five subjects who had a low score of recognition ($p < 0.01$). All of them had the lowest scores in reading, understanding, or remembering the text. We propose that this procedure of successive recognition imitates a reading process and can be used as a test for MS functioning.

◆ **Magnocellular function contributes to reading and attention in children**

R E Pye, P M Riddell (School of Psychology and Clinical Language Science, University of Reading, Earley Gate, Reading RG6 6AL, UK; e-mail: r.e.pye@rdg.ac.uk)

Children with dyslexia have been shown to differ from control participants during standard serial visual-search tasks. It has been suggested that this could result from a deficit in the magnocellular system, by reducing the efficacy of the feedback system mediating visual attention. We tested 67 children (6–10 years old) on word reading ability, motion coherence (a common test of magnocellular function), and visual search. The visual-search task required the children to identify three-symbol target strings amongst distractors in a paragraph. This test was designed to mimic reading. Results showed that motion-coherence threshold, visual-search ability, and reading ability were all significantly correlated. Children who were poor readers were poor at motion detection and visual search; those who were good motion detectors had high sensitivity on the visual-search task. While the correlation between reading and visual search remained after partialling out motion-coherence thresholds, the correlation between reading and motion coherence was no longer significant when visual-search ability was partialled out. This suggests that, while magnocellular function contributes to both reading and visual search, there is also an independent contribution of visual search to the reading process indicating other common processes.

[Supported by the University of Reading.]

◆ **Investigating poor visual performance in children with Down syndrome**

J-A Little, J S Lauritzen¶, J M Woodhouse§, K J Saunders¶ (Vision Science Research Group, University of Ulster, Cromore Road, Coleraine BT52 1SA, Northern Ireland, UK; §School of Optometry and Vision Science, Redwood Building, King Edward VIIth Avenue, Cardiff CF10 3NB, Wales, UK; e-mail: ja.little@ulster.ac.uk)

Children with Down syndrome (DS) show reduced visual performance compared to their developmentally normal peers (Woodhouse et al, 1996 *Journal of Intellectual Disability Research* **40** 49–55). The origin of this deficit is not clear. To isolate the contribution of cortical and optical factors, in the present study we measured grating acuity (GrA) [optical factors and retinal integrity] and Vernier acuity (VeA) [cortical processing] in age-matched 9–16-year-old children with and without DS. VeA was measured with a novel contrast masking protocol displaying a sub-pixel offset, designed to decrease testing distances (Lauritzen et al, 2005 *Perception* **34** Supplement, 108). VeA was derived from contrast thresholds obtained by a 2AFC QUEST adaptive staircase procedure. GrA was similarly measured. VeA and GrA were invariant with age in both groups. The mean VeA and GrA for the DS group were 39.8 (controls 14.6) and 185.5 (controls 45.6), respectively (all values in seconds of arc). GrA and VeA were both significantly reduced in DS compared to controls, with GrA demonstrating the largest discrepancy. Optical quality has greater impact on GrA than VeA, implicating poor optics in the reduced visual performance in DS. [Research funded by the Department of Education and Learning, Northern Ireland.]

◆ **Stepping stones across the river: Visually guided planning of locomotion in children and adults**
D A Cowie, L Smith, O J Braddick, J Atkinson¶ (Department of Experimental Psychology, University of Oxford, South Parks Road, Oxford OX1 3UD, UK; ¶ Department of Psychology, University College London, Gower Street, London WC1E 6BT, UK; e-mail: dorothea.cowie@psy.ox.ac.uk)

Motor planning uses visual information to predict end-state and select appropriate action sequences. Most investigations of such planning, including its development, have been limited to manual actions. Our 'river crossing' task is designed to examine visually guided planning of locomotion. Participants have to cross a 'river' using stepping stones forming two alternative paths. The final gap is easy in one path, and of variable length and difficulty in the other. The initial movement may require either easy or difficult foot placements. For adults, and groups aged 3.5, 4.5, and 6 years, the choice of initial action shows significant effects of final gap size, age, and age × gap interaction. This demonstrates complex planning in the locomotor domain as early as at the age of 3.5 years, much earlier than in manual tasks (Smyth and Mason, 1997 *Journal of Child Psychology and Psychiatry* **38** 1023–1037; Newman, 2001, PhD thesis, University College London). Initial planning abilities are followed by substantial developmental refinement. Children's planning errors can be contrasted with their near-perfect performance on a control task requiring direct perceptual judgment of gap size from the starting location. This task will be extended to longer forward planning (more stepping stones) and the need to process further visual information for avoidance (a projected 'animal').

[Supported by Medical Research Council programme grant G7908507 and a MRC research studentship to DC.]

◆ **Visual perception of elliptic movements in 7–11-year-old children: Influence of motor rules**
J-P Orliaguet, C Ildei, D Meary (Laboratoire de Psychologie et Neuro-Cognition, UMR CNRS 5105, Université Pierre Mendès France, F 38040 Grenoble Cedex 9, France; e-mail: jean-pierre.orliaguet@upmf-grenoble.fr)

We analysed the influence of motor rules on the visual perception of human movements. To this end, the ability of 7–11-year-old children to judge perceptually elliptic motions was investigated. In a perceptual task we tested the isochrony motor principle, that is the tendency to maintain constant the duration of movement across change in trajectory length. Participants had to adjust the velocity (the period) of a dot depicting an elliptic motion. The size of the ellipse (2.94 cm to 53 cm) was changed in each trial. For each subject, the relation between the period chosen and the ellipse perimeter was analysed. Results showed a perfect match with data obtained in motor production. From the age of 7 years perceptual adjustments are in agreement with the isochrony principle. The results are discussed in terms of motor–perception relationships.

◆ **Contrast sensitivity of amblyopic and squint children**

V Zhuravsky¶, N V Galinovskaya, N N Usova ([¶ Specialized School Kindergarten 27 for Visually Impaired Children], Gomel State Medical University, Gomel Regional Special Clinical Hospital, Meditsinskaya 6, 246027 Gomel, Belarus; e-mail: valzhuravski@mail.ru)

We measured the contrast sensitivity at ages of 3–6 years in healthy children, and registered contrast sensitivity changes among children with amblyopia and strabismus. We used standard methods.

We measured contrast sensitivity by presenting sinusoidal gratings of different contrast on a calibrated display of a personal computer. Gamma function has been corrected. We measured contrast threshold by the staircase method. We organised two groups of children: one with normal vision (the control group) and one with those who suffered from amblyopia and strabismus. For all participants we evaluated visual acuity, contrast sensitivity, and refraction, and provided bio-microscopy and ophthalmoscope measurements. Age standards of contrast sensitivity were determined for children of the age group of 3–6 years. Preliminary results of measurements on seventy-four children with amblyopia permitted us to divide amblyopic patients into different groups. Contrast sensitivity in amblyopic patients can be reduced either in the whole spatial-frequency diapason or in a narrow range of medium or high spatial frequency compared to normal children. That subdivision was based on different degrees of contrast sensitivity reduction and on a different spatial-frequency range where such a reduction was observed among children suffering from amblyopia and squint.

◆ **Peculiarities of colour vision testing in children**

M Sharikadze[¶], A Kezeli (Laboratory of Vision Physiology, I Beritashvili Institute of Physiology, Georgian Academy of Sciences, Gotua14, 0160 Tbilisi, Georgia [[¶] also Institute of Medical Psychology, Ludwig-Maximilians University of Munich, D 80336 Munich, Germany]; e-mail: msharikadze@yahoo.com)

When Ishihara pseudoisochromatic plates are used in testing the colour vision of children, some naming errors often occur. Then arrangement tests such as the Farnsworth D15 and the Lanthony's D15d tests should be used to reveal whether these errors indicate real visual deficits. We aimed to uncover the problems related to such testing. Using these three tests, we studied colour vision of fifty-six female and sixty-four male healthy children (aged 6–12 years). The Ishihara and D15 tests were performed with minor errors, while in the D15d test, 30% of children made tritan errors. We suppose that these errors are due to changes in strategies children use. First, they relied on similarity between a reference colour sample and the first chip to correctly arrange the first 5–6 chips. Hence, the 7th–9th samples seemed to be different. Then their strategy changed to grouping of the remaining samples: N7–N9 in one group and N10–N15 in the other. We think that these commonly used tests require different levels of cognitive ability that should be taken into account when children are tested. Insights into decision-making processes of pupils can be interesting subject for further investigations.

◆ **Refractive errors in auditory impaired children of preschool and junior school age**

T Y Cherepennikova, N A Krasnoperova, G I Rozhkova[¶] (Pedagogical State University, Malaya Pirogovskaya 1, 119992 Moscow, Russia; [¶] Institute for Information Transmission Problems, Russian Academy of Sciences, Bolshoi Karetnyi 19, 127994 Moscow, Russia; e-mail: olevashov@mail.ru)

Refractive state of the eyes was studied in 109 subjects (aged 4.5–12 years) from special institutions (kindergartens and schools) for auditory impaired children and in 192 children with normal hearing. In the population of auditory-impaired children, a larger percentage of refractive anomalies was found than in children with normal hearing. The difference was mainly due to hyperopic anomalies although anomalies of myopic type were prevalent both in auditory-impaired and control children. Since there was no essential dependence of the difference on age, one could suppose that the increased proportion of hyperopic eyes reflected some general retardation in the development of auditory-impaired children and, in particular, slower emmetropisation of their eyes with age. In agreement with the available data (eg Woodruff, 1986 *American Journal of Optometry and Physiological Optics* 63 668–675), we found that the number of refractive errors was minimal in the subgroup of children with inherited deafness. The number of anomalies appeared to be maximal (exceeding the control level by about 40%) in the subgroup of children with acquired hearing loss. It is suggested that the initial diseases or medicaments leading to hearing loss had multiple consequences and, probably, influenced eye growth more directly.

◆ **Age peculiarities of the influence of gender and eye-dominance on the perception of the Poggendorff figure**

I I Shoshina, L N Medvedev[¶], E S Fedorova[¶] (Department of Nature, Krasnoyarsk State Pedagogical University, Lebedevoi 89, 660049 Krasnoyarsk, Russia; e-mail: shoshina@kspu.ru)

Accuracy of judging the spatial arrangement of the elements in the Poggendorff figure increases with age. The degree of the illusion depends on eye dominance and gender. The dominant eye was determined by the Rosenbach test. For males with any type of eye dominance, the greatest rate of decrease of the illusion was observed at the age of 7.5–9 years, for females at the age of 9–12.5 years. Females aged 7.5, 9, 12.5, and 18.5 years with a left dominant eye showed the

most exact estimation of the Poggendorff figure. Males at various stages of ontogenesis did not have such a clear benefit of the left dominant eye. It was established that for 7.5-year-olds, more exact estimation of the interposition of the figure elements was demonstrated by subjects with a right dominant eye; in 9-year-olds, as a whole, the differences were absent, and among the 12.5-year-olds, the right-eye dominant subjects performed slightly better. However, in both males and females aged 18.5 years, higher accuracy in judging the spatial arrangement of the elements in a Poggendorff figure was observed in subjects with a left dominant eye. Irrespective of the type of eye dominance, males showed more exact perception of the Poggendorff figures than females. [Supported by the Krasnoyarsk Regional Fund for Science, 12F030M.]

◆ **Variability of Müller-Lyer illusion assessed by means of printed and computer-generated test images**

V V Ognivov, V S Tokareva (Institute for Information Transmission Problems, Russian

Academy of Sciences, Bolshoi Karetnyi 19, 127994 Moscow, Russia; e-mail: ww00@yandex.ru)

Geometrical illusions are usually assessed by means of printed or computer-generated images. In testing with printed images, the subject is in a situation of a 'forced' choice from among ready samples, so the range of possible errors is limited. In the computer approach, this restriction is absent, as the subject produces equalising himself. The task of our research was to compare the results obtained with the use of printed and computer-generated images. In both cases, the procedure of illusion 'neutralisation' was employed, ie subjects chose or generated independently images in which compared parts seemed to be equal. Subjects were schoolchildren aged 6–7 years and students. In printed images, the expected error value was limited to 40%, however, in computer testing, the errors appeared to reach 60%. However, students' computer and 'paper' assessments of the illusion produced average errors and standard deviations that appeared to be practically identical (mean: 20.7 vs 20.2; SD: 10.6 vs 10.7) and corresponded well to the results of other computer studies (eg Predebon, 2000 *Perception & Psychophysics* **62** 1086–1098). However, in schoolchildren, the difference was essential (mean: 34.1 vs 26.6; SD: 13.7 vs 10.2). Therefore, the variability of the Müller-Lyer illusion in children needs further investigation. [Supported by Department of Biological Sciences, Russian Academy of Sciences, Program 2006.]

◆ **Differential right-hemispheric aging: Evidence from a chimeric face processing task with younger and older adults**

S Rossit, S H Butler, M Harvey (Department of Psychology, Glasgow University,

58 Hillhead Street, Glasgow G12 8QB, Scotland, UK; e-mail: s.rossit@psy.gla.ac.uk)

A right-hemisphere bias for face processing has been reported consistently in the face-processing literature. Studies employing chimeric facial stimuli, where the left and the right sides of the face are different, reliably report that both young and older observers tend to bias their responses significantly toward the information on the left, supposedly reflecting this right-hemisphere advantage. However, there is also converging evidence that tasks that selectively engage the right hemisphere may be executed in a different fashion in an older compared to a younger sample, either due to developmental changes in cerebral lateralisation, or selective hemispheric aging. We presented gender-based chimeric face images at brief, medium, and long exposure durations to samples of younger and older adults, and observed significant left perceptual biases in all conditions. However, we also obtained a significant effect of age group, namely that mean perceptual biases for the older adults were considerably diminished. Interestingly, with brief presentations, significant perceptual biases were only observable in our younger sample. We argue that these findings can be explained in the context of the differential aging hypothesis.

[Supported by the Royal Society of Edinburgh, EU, and Fundação para a Ciência e a Tecnologia (SFRH/BD/23230/2005).]

◆ **Flickering light in combination with mesopic illumination causes reorganisation of the distribution pattern of cytochrome oxidase activity of visual area 17 neurons in kittens**

F N Makarov, N S Merkulieva (Laboratory of Neuromorphology, Pavlov Institute of Physiology, Russian Academy of Sciences, nab. Makarova 6, 199034 St Petersburg, Russia; e-mail: fnm@infran.ru)

A changed visual environment has been known to markedly modify development of visual pathways. The goal of the present work was to study the effect of flickering light on the development of visual channels. It was suggested that flickering light in combination with mesopic illumination could selectively activate the Y channel. To check this suggestion, three groups of kittens were reared until the age of 8 weeks. The first group of kittens was reared since the eye opening under conditions of mesopic illumination. The second group was stimulated daily for 2 h by a light flickering at a frequency of 15 Hz and reared under normal illumination. The third group

was stimulated by the same flickering light, but reared under mesopic illumination. We found that only in the third group of kittens an alternation of dark patches [with a high level of cytochrome oxidase (CO) activity] and light ones (with a low level of the CO activity) occurred in the layer IV of area 17. The sizes of the dark patches amounted to 370–550 μm and the intercentre distance to 700–1000 μm . We suggest that the periodicity of CO is a result of activation of the Y channel.

◆ **Newborns' face recognition is based on low spatial frequencies**

A de Heering (Department of Cognition and Development and Laboratory of Neurophysiology, Université Catholique de Louvain, 10 place du Cardinal Mercier, B 1348 Louvain-la-Neuve, Belgium; adelaidedeheering@psp.ucl.ac.be)

Newborns are able to recognise faces, but little is known about the kind of information they rely on to perform this task. On the basis of the functional properties of the visual system at birth, as described by the newborns' contrast sensitivity function, it may be hypothesised that low spatial frequencies (LSFs) play a critical role in driving newborns' ability to recognise faces. Two experiments were conducted testing newborns with the habituation technique and filtered faces at different cutoff points (1 cycle deg^{-1} and 0.5 cycle deg^{-1}). In experiment 1, newborns recognised the face to which they have been habituated in the low-pass condition (LSF group < 1 cycle deg^{-1} filtering) but not in the high-pass condition (HSF group > 1 cycle deg^{-1} filtering). In experiment 2, newborns also discriminated between the habituated and the novel face in the low-pass (LSF group < 0.5 cycle deg^{-1} filtering) but not in the high-pass condition (HSF group between 0.5 and 1 cycle deg^{-1}). Results support the hypothesis of an LSF advantage in individual face recognition at birth. Within the range of visuo-perceptual information detected and processed at birth (0 to 1 cycle deg^{-1}), only the coarser visual cues conveyed by 0 to 0.5 cycle deg^{-1} provide the newborn with critical source of information for recognising faces.

◆ **Effect of colour on implicit and explicit memory**

V Salvano-Pardieu, P Lafon, C Giraudeau¶, F Florer§, C Collée¶, L Barres¶, R Fontaine (Laboratoire de Psychologie, EA 2114 [¶Département de Psychologie], Université de Tours, 3 rue des Tanneurs, BP 4103, F 37041 Tours Cedex 1, France; §Department of Psychology, Barnard College, Columbia University, 415L Milbank, New York, NY 10027, USA; e-mail: veronique.pardieu@wanadoo.fr)

We investigated in two experiments the effect of colour on implicit and explicit memory in 10-years-old children. After the reading (5 min) of each text, and a calculation task (5 min), they completed word stems (5 min). For the implicit task, they completed each stem with the first word that came to mind. For the explicit task, they completed each stem with a word they remembered from the text. Each experiment lasted 1 h. In the first experiment, four conditions were presented to forty-four participants, two with text and word stems of the same colour (respectively black and red) and two with text and word stems of different colour. Results showed a significant improvement in implicit memory compared to explicit task ($F_{1,43} = 5.07$, $p < 0.05$). In the second experiment (fifty-six participants), the texts involved a colour contrast: 20 target words differed in colour (black or red) from the other words of the text. The word stems were either the same colour as the text, or the same colour as the target words. This time, a significant improvement was observed in explicit memory ($F_{1,55} = 4.67$, $p < 0.05$). The implication of these effects for the pedagogy are discussed.

COMBINING FEATURES INTO FIGURES, OBJECTS, SCENES

◆ **The involvement of the human visual cortical areas in early detection of the first- and second-order object features**

E S Mikhailova, A V Slavutskaya, V A Konishev, I A Shevelev (Institute of Higher Nervous Activity and Neurophysiology, Russian Academy of Sciences, 117485 Moscow, Russia; e-mail: esmikhailova@mail.ru)

To characterise detection of the first-order and second-order features (bars and crosses) in human visual cortex, 34-channel recording of visual evoked potentials (VEPs) was carried out in twelve subjects under the presentation of these stimuli. In VEPs to crosses, the early P1 wave (peak latency 100–120 ms) occurs with shorter latency and larger amplitude than in VEPs to bars; the former is most pronounced in the inferior temporal area. Two-dipole algorithm was used to estimate dynamic localisation of the equivalent current dipole (ECD) of P1 wave. In the real head model based on individual MRIs we found the first ECD in the occipital cortex for all stimuli. Meanwhile, the second dipole of P1 was found in the intra-parietal cortex for crosses and in subcortical zones for bars. The spherical model revealed different ECD localisation of P1 for bars and crosses in the occipital cortex: an average position of ECD for crosses was significantly

(20 mm, $p < 0.01$) shifted laterally from ECD for bars. The data indicate pronounced involvement of the extrastriate cortical fields of the human visual cortex in early detection of second-order image features.

[Supported by the Russian Foundation for Basic Research (# 05-04-49649).]

◆ **When perception of object motion fails: Biases for simple shapes moving along non-cardinal axes**

C M Magnussen, G Löffler (Department of Vision Sciences, Glasgow Caledonian University, Cowcaddens Road, Glasgow G4 0BA, Scotland, UK; e-mail: camilla.magnussen@gcal.ac.uk)

Survival can depend on the veridical perception of object motion. It is widely assumed that perception is accurate when moving targets contain features. We investigated this assumption with different object shapes and orientations. Squares, octagons and circles with inner diameters of 4.85 deg translated for 195 ms at 5 deg s⁻¹ along 16 different directions (0° to 360°). In symmetric conditions, polygons were oriented such that a corner or a side was aligned with the direction of motion. In asymmetric conditions, polygons were tilted relative to the direction of motion. Object motion along cardinal axes was always correctly judged, regardless of shape and orientation. Biases along oblique axes were small (< 10°), when objects were balanced spatially around their motion vectors (circles or symmetric polygons). In the asymmetric conditions, biases were as large as 25°. Direction judgments were biased towards the nearest corner or side of the polygon, depending on the orientation and the shape of the object. Features (eg corners) are thought to be central to motion processing because they signal veridical motion. However, even when a host of features are present (eg octagon), perception for oblique directions exhibits strong biases. Surprisingly, stimuli without features (circles) show smaller biases than objects containing multiple features. [Supported by EPSRC Grant No. GR/S59239/01.]

◆ **Human visual evoked potentials to bars and cross-like figures**

A V Slavutsкая, E S Mikhailova, V A Konishev (Institute of Higher Nervous Activity and Neurophysiology, Butlerova 5A, 117485 Moscow, Russia; e-mail: slavanna@yandex.ru)

Our study was aimed at the mechanisms of the first-order and second-order feature detection in the human visual cortex. For nineteen healthy subjects averaged visual evoked potentials (VEPs) to sets of bars and crosses with different orientation (0°, 45°, 90°, 135°) were recorded from 34 electrodes (system Neocortex-Pro, Neurobotics, Russia). Stimulus size was 18.8 deg, and its duration was 100 ms. VEPs in the visual areas show larger amplitudes and shorter latencies (P1, N2, and P3) for crosses than for bars. Different regional gradients were found for bars and crosses: lengthening of P1 peak latency from the occipital to the temporal cortex occurs mostly for bars, while P1 amplitude increase occurs mostly for cross-like figures. For the right inferior temporal lobe, our analysis of the VEP current source shows more activity to crosses than to bars. These observations are in good agreement with (i) bigger magnitude and shorter latencies of neuron responses to crosses vs bars in the cat striate cortex, (ii) sensitivity of cells in the monkey inferior-temporal cortex to star-like figures, and (iii) relatively better human recognition of incomplete figures with corners rather than with bars.

[Supported by RFBR grants 05-04-49649.]

◆ **Human perception and recognition of metric changes of part-based dynamic novel objects**

Q C Vuong, J Schultz, L Chuang (Department of Cognitive and Computational Psychophysics, Max Planck Institute for Biological Cybernetics, Spemannstrasse 38, D 72076 Tübingen, Germany; e-mail: quoc.vuong@tuebingen.mpg.de)

The role of object parts is a key issue in object recognition. Here we investigated whether observers encode qualitative (eg straight versus curved part) or metric information of parts (eg curvature magnitude), and whether the information that is encoded can be affected by motion. To address these issues, we constructed a novel set of objects composed of parts that can vary metrically along different dimensions (eg tapering and bending) to create qualitatively different parts. In a same/different matching task, we presented two objects rigidly rotating in the same or different direction, and had observers judge whether these objects were the same or different. We varied the pair of objects along an 'identity' axis by morphing between two exemplars. A cumulative Gaussian function explained the effect of morph level, suggesting that observers encoded metric information. There was a slight shift of the psychometric function for same versus different motion. Overall, our results suggest that observers are sensitive to metric information, even for objects with salient part structure. We are currently investigating with fMRI how object parts and motion influence neuronal object processing.

[Supported by a Max-Planck-Gesellschaft Scholarship.]

◆ Semantic and perceptual dimensions of people in scenes for image indexing

A Guérin-Dugué, N Otto¶, A Oliva§ (Laboratory of Images and Signals, INPG, 36 avenue Félix Viallet, F 38031 Grenoble, France; ¶Communication Langagière et Interaction Personne – Système [CLIPS], UMR CNRS/UJF/INPG 5524, 385 rue de la Bibliothèque, F 38041 Grenoble Cedex 9, France; §Brain and Cognitive Sciences, Massachusetts Institute of Technology, 77 Massachusetts Avenue, Cambridge, MA 02139, USA; e-mail: anne.guerin@lis.inpg.fr)

In visual information retrieval, one of the main challenge is to take into account the user, in his/her perceptual and cognitive dimensions, at each stage of the retrieval process. The difficulty is to choose the space of features for suitable image representation to provide an effective indexing process. Inside the very wide domain of scene interpretation, we focus on the impact of people, on the scene semantics. It is well known that people in the images greatly influence the categorisation process of scenes. To go further, our objective was to extract perceptual and semantic dimensions related to the importance of people in scene interpretation. 11 criteria were analysed; 6 were linked to spatial organisation and 5 were linked to semantics. The database was composed of 120 images gathering all these criteria. Twenty-five subjects were invited to distribute the images into ranked groups, if the presence of people is more or less important, if one would make the description of the scene. Twenty subjects were selected for which all the correlations (Kendall's τ) of their judgment were significant. On this basis we justify and provide semantic and perceptual dimensions for content-based image indexing.

TIMING AND TEMPORAL DYNAMICS

◆ Human estimation of short time intervals

D N Podvigina, D A Fahretdinova¶, N F Podvigin (Pavlov Institute of Physiology, Russian Academy of Sciences, nab. Makarova 6, 199034 St Petersburg, Russia; e-mail: daria-da@yandex.ru)

In psychophysical experiments we studied how observers estimate short time intervals within the 30–1930 ms range. This interval included 20 sub-intervals, which differed from each other by 100 ms. Estimation of such short time intervals has not been studied before. Subjects estimated unfilled time intervals bounded with visual stimuli (2 bright thin lines). Absolute error of estimate of each sub-interval was about 12% of its real duration which indicates high precision of estimate of such short intervals. Subjective estimates of the time intervals depended linearly on the real values. Moreover, intervals shorter than 1130 ms tended to be overestimated, while longer intervals tended to be underestimated. For the studied range of time intervals, we show that interval of about 1130–1400 ms is most precisely estimated, and we consider it as a neutral interval. Our data show that 75% of subjects created a subjective discrete scale of time estimate including about 4 scores. We believe that further experiments will show that this scale agrees with Miller's law (over all stimuli presented, untrained subject can discriminate 72 successfully), which characterises the functioning of the human sensory systems. We discuss possible neuronal organisation of the system involved in estimating short time intervals (see also Podvigin et al, 2003 *6th International Congress of the Polish Neuroscience Society, Strzekecino, Poland*, 19–23 July, pp 45–47; abstracts of the satellite symposium *Time, Cognition, Thinking*, website: <http://www.brains.nencki.gov.pl>).

◆ Temporal articulation of sensory events and perception of time

G Plomp, S Gepshtein, C van Leeuwen (Laboratory for Perceptual Dynamics, Riken Brain Science Institute, 2-1 Hirosawa, Wako-shi, Saitama 351-01498, Japan; e-mail: gplomp@brain.riken.jp)

Participants viewed two sequentially presented suprathreshold visual stimuli and reported which one appeared to last longer in a two-alternative forced-choice procedure. We measured the perceived duration of the stimuli and precision of duration discrimination. To examine the effect of temporal articulation of sensory events on the perception of time we (i) modulated the brightness of the visual stimuli in time; (ii) played concurrent auditory stimuli whose amplitudes were or were not modulated in time. Neither the visual nor auditory modulations were informative of actual stimulus duration. Brightness modulation increased the perceived duration of visual stimuli. The perceived duration of unmodulated visual stimuli increased when they followed visually modulated ones, which is evidence of entrainment. Auditory modulation did not alter the perceived duration of visual stimuli. Discrimination of the visually stimuli obeyed Weber's law, for both modulated and unmodulated stimuli. Auditory stimuli did not affect precision of discrimination. The results show that visual (but not auditory) articulation elongates the perceived time of visual events. We compare our results with predictions of entrainment models of time perception.

- ◆ **Influence of the speed of environmental stimuli on estimating the duration of a static stimulus**
S Estaún Ferrer Sr, J Mate, A Pires (Departament de Psicologia Bàsica, Evolutiva i de l'Educació, Universitat Autònoma de Barcelona, E 08193 Bellaterra, Spain; e-mail: santiago.estaun@uab.es)

The objective of this work was to verify the temporal estimation made by subjects for a stimulus that appears in a static or dynamic environment. The storage size model by Ornstein [1969 *On the Experience on Time* (New York: Penguin)] and the change/segmentation model by Poynter [1989, in *Time and Human Cognition: A Lifetime Perspective* Eds I Levin, D Zakay (Amsterdam: Elsevier) pp 305–321] provide divergent explanations. The psychophysical method of constant stimuli, together with an initial experiment, were used to estimate the duration of a red square appearing for 1.5 s surrounded by blue spheres [both static and in movement (fast and slow)]. In a second experiment, the differential threshold was determined for six different speeds (0.9, 1.2, 1.4, 1.6, 1.8, and 2.1 s). Results suggest that, within the contextual surroundings of rapid movement, there is an underestimation of standard stimulus time (1.34 s), but this, in turn, is overestimated (1.58 s) within the contextual surroundings of slow movement.

- ◆ **Perception of duration for equiluminant stimuli**
G M Cicchini (Department of Psychology, Università di Milano-Bicocca, 1 piazza dell'Ateneo Nuovo, I 20126 Milan, Italy; e-mail: guido.cicchini@unimib.it)

There is now growing evidence that the perception of duration is not handled by a general-purpose timing mechanism but rather relies on different mechanisms depending on the modality. However, not much is known whether the perception of duration within the same modality can rely upon a similar diverseness of mechanisms. For this reason we performed an experiment in which an equiluminant colour-modulated Gabor had to be matched for duration to a reference luminance-modulated Gabor patch. The Gabor patches had spatial frequency of 1 cycle deg⁻¹ and their contrast was chosen to be three times the threshold for visibility. We found that the colour-modulated patches had to be presented for longer physical times to match the duration of the luminance-modulated patch. The effect held for all the reference durations tested (200 ms–600 ms) and was larger for longer test durations. These results can hardly be reconciled with the existence of a single clock which is triggered by the onset and the offset of the visual stimuli.

- ◆ **Asynchronous perception of colour and motion: Effects of trajectory position**
A Gauch, D Kerzel (Department of Psychology, University of Geneva, 40 boulevard du Pont d'Arve, CH 1205 Geneva, Switzerland; e-mail: angelique.gauch@pse.unige.ch)

A colour change that is physically simultaneous with the onset of object motion may be perceived as occurring before the initial displacement. In contrast, a coloured flash during object motion is displaced in the direction of motion, suggesting that colour is perceived after motion. These apparently conflicting results could be reconciled by assuming differential latencies of motion perception—latencies are longer at the onset of object motion than during object motion. Hence, we suppose that, when a colour change occurs at the beginning of object motion, it will be perceived before motion onset because the latency of motion perception is longer than the latency of colour perception (which is always constant). During object motion, latencies of motion perception decrease and are eventually shorter than latencies of colour perception. We determined perceptual asynchronies at motion onset and during the trajectory with two moving bars as stimuli. Our results indicate that motion is perceived before colour when the colour change occurs during the trajectory, but no asynchrony was found at motion onset. To clarify the discrepancy between studies that demonstrated shorter latencies for colour at motion onset, a number of control experiments were conducted.

[Supported by the Swiss National Foundation 10011-107768/1.]

- ◆ **Breaking the stability of perceptual instability: Temporal dynamics of ambiguous figure reversal and interference from distractor patterns**
V Conrad, J S McDonald, J Schultz (Max Planck Institute for Biological Cybernetics, Spemannstrasse 38, D 72076 Tübingen, Germany; e-mail: verena.conrad@tuebingen.mpg.de)

During continuous viewing of multistable figures, such as the Necker cube, perception alternates between equally valid solutions. So how can perceptual experience be stable given that various alternative interpretations of the same physical stimulus are available? Previous demonstrations with bistable stimuli have revealed that a repetitive intermittent presentation leads to a stabilisation of the percept. Recent research findings suggested that interleaved presentation of several ambiguous stimuli does not disrupt the perceptual stabilisation of each reversible pattern, suggesting that perceptual 'memory stores' coexist independently for each representation. Interference effects were only obtained for structurally similar stimuli. In the present study, we adopted Maier

et al's interleaved presentation paradigm to investigate the effects of interfering ambiguous patterns upon transition probability and the stabilisation process. Rather than manipulating structural similarities between interleaved ambiguous stimuli, we sequentially presented ambiguous figures that share equivalent reversal processes such as figure-ground segregation or perspective reversal. The results reveal that perceptual dominance time of the ambiguous test stimulus decreases compared to periods during which a blank interval is presented, indicating an effect of interference from the distractor. Interaction between reversal processes influences the stabilisation of perception that is normally observed during repetitive intermittent presentation with blank intervals. [Supported by the German Academic Foundation and the Max Planck Society.]

◆ **Object-based and location-based selection in visual temporal displacements**

E V Pechenkova (Department of Psychology, Lomonosov Moscow State University, Mokhovaya 11, corp. 5, 125009 Moscow, Russia; e-mail: e_v_pec@mtu-net.ru)

An observer can perceive simultaneous events as successive and vice versa if the events occur within 500 ms. This phenomenon is often referred to as temporal displacements. Displacements can be evoked in a task of matching of visual feature pairs alternating at high rates (eg to determine whether red is paired with the right-tilted or left-tilted elements of the display). Holcombe and Cavanagh (2001 *Nature Neuroscience* 4 127–128) have shown that subjects experience substantial difficulties while reporting the orientation paired with a certain colour when features are spatially separated. Conjoining spatially separated features within the same object does not improve performance. Here, superimposed contours of two objects (the sun and a cloud) have been used to test if object-based selection plays any role in emergence of temporal displacements. In four conditions, the key colour and to-be-reported orientation were either spatially integrated or separated, and also were paired within either same or different objects. The accuracy threshold and the proportion of reports/refusals for the subthreshold rates were measured. The results show that temporal displacements may be due to difficulties in both object-based and location-based selection, and that object-based selection supports focusing on the task while not guaranteeing successful performance.

◆ **Automatic integration of visual, tactile and auditory signals for the perception of sequences of events**

J-P Bresciani, F Dammeier, M O Ernst (Max Planck Institute for Biological Cybernetics, Spemannstrasse 38, D 72076 Tübingen, Germany; e-mail: bresciani@tuebingen.mpg.de)

Sequences of visual flashes, tactile taps, and auditory beeps were presented simultaneously. For each session, subjects were instructed to count the number of events presented in one modality (focal modality) and to ignore the other modalities (background). The number of events presented in the background modality(ies) could differ from the number of events in the focal modality. The experiment consisted of nine different sessions, all nine combinations between visual, tactile, and auditory signals being tested. In each session, the perceived number of events in the focal modality was significantly influenced by the background signal(s). The visual modality, which had the largest intrinsic variance (focal modality presented alone), was the most susceptible to background-evoked bias and the less efficient in biasing the other two modalities. Conversely, the auditory modality, which had the smallest intrinsic variance, was the less susceptible to background-evoked bias and the most efficient in biasing the other two modalities. These results show that visual, tactile, and auditory sensory signals tend to be automatically integrated for the perception of sequences of events. They also suggest that the relative weight of each sensory signal in the integration process depends on its intrinsic relative reliability.

NEURAL CODING

◆ **The inefficiency of visual search for a target differing in duration is not explained by memory loss**

M J Morgan (Applied Vision Research Centre, City University, Northampton Square, London EC1V 0HB, UK; e-mail: m.morgan@city.ac.uk)

Visual search for a target differing in duration from up to seven temporally asynchronous distractors is much harder than search for a target differing in size (Morgan, Giora, and Solomon, paper presented at VSS 2006). While the increase in Weber fractions for size with distractor number is well explained by signal detection theory, the increase for duration is much greater. A possible explanation is that the duration task imposes a memory load lacking in the spatial task, where the targets were present simultaneously. We ruled out this explanation by showing that a temporal *n*AFC task for size with a 0.5 s ISI was still easier than the temporal task. In an attempt to find a spatial task of comparable difficulty to the temporal, we had the target and each distractor start at a random size and then grow in size during their presentation to their

final size, at which point they disappeared. The task was to identify whether the target had a larger or smaller final size than the distractors. This task was hard, but still not as hard as the equivalent temporal one. We conclude that observers probably have no access to independent clocks at different locations, but only to a single master clock.

[Supported by BBSRC.]

◆ **Study of high-frequency oscillations in cat lateral geniculate nucleus neurons**

T V Bagaeva, N F Podvigin, D N Podvigina, A A Kunitskij¶ (Pavlov Institute of Physiology, Russian Academy of Sciences, nab. Makarova 6, 199034 St Petersburg, Russia; ¶ Hospital of Cardiology, Polutrovsky pr. 12, 195197 St Petersburg, Russia; e-mail: tat36@yandex.ru)

The high-frequency range (20–100 Hz) of oscillatory processes in the responses of cats LGN neurons was studied. We found earlier (Podvigin et al, 2004 *Neuroscience Letters* **361** 1–3, 83–85) that there are three kinds of neurons generating oscillations of three types (26.95 ± 4.35 , 52.02 ± 9.05 , and 85.79 ± 7.19 Hz). The study of oscillation characteristics has been extended to the 90–250 Hz range. Neuronal responses to light test bar and brightness gradient vector with their different orientations were analysed. 75 890 responses of 48 neurons were recorded in 18 experiments. Spectral characteristics (SC) of 1546 peristimulus histograms of neuronal responses to ON and OFF stimuli adequate for these neurons were analysed to find the frequency of the oscillations. We studied how the oscillation frequency and intensity of neuronal responses depend on the type of the test stimulus, its spatial brightness characteristics, and orientation of the test image. 13 neurons showed oscillatory activity within 90–250 Hz range. Distribution of SC peak values had a maximum at about 110 Hz. The mean frequency of oscillations was 108.36 ± 16.34 Hz. Oscillation frequency did not depend on the type of the test stimulus, was not altered by changes in orientation of the test image, and had its maximum intensity under preferred stimulus orientations within neuronal receptive fields.

[Supported by Russian Foundation for Basic Research, grants 02-04-49834 and 05-04-48067, and ‘Science to Medicine’ project.]

◆ **On mechanisms of synchronisation of impulses in impulse reactions of neurons in neuronal pools**

N F Podvigin, T V Bagaeva, D N Podvigina, M P Granstrem, E G Yakimova (Pavlov Institute of Physiology, Russian Academy of Sciences, nab. Makarova 6, 199034 St Petersburg, Russia; e-mail: podvigin@yandex.ru)

Mechanisms of control of impulse synchrony rate in impulse reactions of neurons within neuronal pools were studied. The results showed (Podvigin et al, 2000 *Doklady Akademii Nauk* **375** 552–554; Podvigin et al, 2004 *Homeostasis* **43** 1–6) that impulse synchrony rate in neuron reactions (assessed by cross-correlation analysis results) correlates (coefficient 0.716 ± 0.217) with neuronal pool excitation level. Neuronal pool excitation was caused by visual stimuli having various spatial brightness characteristics. These data show that neuronal assemblies under study have property of self-synchronisation of impulses generated by them. To reveal if this self-synchronisation principle is correct for other brain systems we used nonspecific excitatory influence to excite neuronal pools—microinjections of glutamic acid into pools. It was proved that the excitatory influence of glutamic acid upon neuronal pools also causes the increase in synchronism of impulse reactions to visual stimuli generated by neurons in the pools. Thus, excitation of neuronal pools caused both by specific influences for the visual system and nonspecific influences results in an increase of impulse synchrony rate in neuronal pool reactions. Such self-synchronisation principle may control the synchronism of impulse currents over the whole possible diapason—from their absolute asynchronism to the highest possible synchronism (for example, from sleep to activity).

[Supported by the Russian Foundation for Basic Research, grants No 02-04-49834 and 05-04-48067, and the Department of Biological Sciences of the Russian Academy of Sciences.]

◆ **The role of the human primary visual cortex in visual perception and visual search**

R Weerda, P Arndt, H Colonius, M W Greenlee¶ (Section of Cognitive Research, Department of Psychology, Carl von Ossietzky University Oldenburg, Ammerländer Heerstrasse 114–118, D 26129 Oldenburg, Germany; ¶ Department of Psychology, University of Regensburg, Universitätsstrasse 31, D 93053 Regensburg, Germany; e-mail: Riklef.Weerda@mail.uni-oldenburg.de)

It is a long-debated question, whether the human primary visual cortex (V1) is part of the neuronal correlate of perceptual awareness. Related to this is the question if the activity of V1 neurons represents more the physical or the perceived stimulus intensity. To test this, a spatial uncertainty paradigm was employed in order to dissociate sensory from perceptual processes. Subjects performed a visual search task within this paradigm while the activity of their V1 neurons was measured with event-related functional magnetic resonance imaging (efMRI).

The subjects' task was to determine which one out of four stimuli had an increased luminance contrast intensity. The blood oxygenation level dependent (BOLD) signals of V1 neurons retinotopically corresponding to the locations of the stimuli were statistically analysed as hits, misses, correct rejections, and false alarms, as in the work reported by Ress and Heeger (2003 *Nature Neuroscience* 6 414–420). The results reveal higher neuronal activity during false alarms than during misses, so that the activity of V1 neurons strongly reflects the perceived intensity of a stimulus irrespective of its physical intensity. This effect is modulated by the intensity of the target stimulus. These results point towards a participation of V1 in the neuronal calculations underlying visual perceptual awareness.

[Supported by the German Research Foundation (SFB 517 "Neurocognition", InterGK "Neurosensory Science and Systems")]

COGNITION, DECISION

◆ **Categorisation labels do not change transitivity in shape space**

N Rezaii, A Abutorabi¶, B Nodoust§ (Shahid Beheshti Medical University, Velenjak Street, Tehran, Iran; ¶ Iran Medical University, Tehran, Iran; § Institute for Studies in Theoretical Physics and Mathematics (IPM), Niavaran, 19395-5 Tehran, Iran; e-mail: neguinerezaii@gmail.com)

According to Tversky's transitivity idea, when a target is judged to be more similar to stimulus A than to B, and more similar to B than to C, then, if the space is transitive, we expect that it would be judged to be more similar to A than to C. In this study, we tried to investigate whether adding categorisation labels (CL) could lead to violations from transitivity in shape space. For this, a shape space was defined consisting of faces that varied along two CLs (male/female and Asian/European labels). During the test phase, faces were so paired that each differed in only one CL. Subjects had to make a choice of match (if the two belonged to the same category) or nonmatch (if not). On the basis of the measured reaction time we defined a transitivity index. The indexes for match (0.97) and nonmatch trials (0.95) were not significantly different ($p > 0.649$, paired t -test). According to our data, addition of CLs does not lead to violations from transitivity rule in a parametric shape space on assuming reaction time as a measure of similarity. However, application of other measures of similarity would be helpful to reveal the role of CLs in transitivity of shape space.

◆ **Visual perception of equilibrium position of composite objects**

F Samuel, D Kerzel (Department of Psychology, University of Geneva, boulevard du Pont d'Arve 40, CH 1205 Geneva, Switzerland; e-mail: Francoise.Samuel@pse.unige.ch)

How accurately and how precisely do we perceive if an object in an unstable position will fall to one side or the other? What are the visual cues these judgments are based on? Possibly, observers use heuristics which replace the physically correct evaluation (ie an evaluation based on the position of the centre of surface, as a centre of mass, in relation to the point of support). In a psychometric study using forced-choice judgments and a presentation time of 1 s, we determined the point of subjective equilibrium (PSE) for various objects composed of two or three adjacent but non-overlapping squares. The PSE was found to differ significantly as a function of object. In order to determine the effective visual cues, we calculated the deviations between PSE and the potential cues (ie various centres of mass, position of summit, lateral extension, angles at the base of the object) for each object. A small deviation indicated that observers used the given cue to make the equilibrium decision. Inter-observer variability was considerable and observers could be classified according to their preferred cue.

◆ **Subliminal visual perception effects on human emotional status**

V Y Ivanova, G A Kulikov, A S Vassertreiguer, A Y Aleksandrov (A A Ukhtomskii Department of Biology and Soil Science, Institute of Physiology, St Petersburg State University, Universitetskaya nab. 7/9, 199034 St Petersburg, Russia; e-mail: vitai@mail.ru)

Most contemporary studies are concerned with conscious perception and its neurophysiological basis. Unconscious forms of visual perception have been shown to be important determinants of human behaviour, but there has been little exploration of the effects of subliminal perception on emotional state. We studied whether emotional state could be modified by subliminal stimuli. The emotional state was evaluated by the functional asymmetry ratio of the EEG. A negative emotional state was evoked by single-themed/unequivocal video passages and was revealed by a predominance of right frontal activation in the α -band. The subliminally exposed video stimuli were presented as part of a positively signed short movie at the beginning of the experiment. The subject of this movie was a prank of a 3-month-old child, accompanied by corresponding infant vocalisations. This movie was selected as a valid species-specific, emotionally positive stimulus.

In the main part of the experiment, an extremely short (30 ms) still from the emotionally positive video was inserted into the end of a negatively signed video segment. According to the functional asymmetry of the EEG, there was a significant difference in comparison with the effect of presenting an initial negative segment. This result points to a significant correction of the negative state on presentation of positive subliminal videos.

◆ **Strategies for storing spatial transformations of chess positions**

V Lyakhovetskii, A Potapov¶, S Ivanov§ (Department of Biomedical Electronics [§ Department of Physical Culture], St Petersburg Electrotechnical University, ul. Prof. Popova 5, 197376 St Petersburg, Russia; ¶ Department of Automatic Image Processing, Vavilov State Optical Institute, Birzhevaya linia 12, 199034 St Petersburg, Russia; e-mail: seva@decosp.spb.ru)

Existing theories regarding the memory of chess players do not pay sufficient attention to the storage of spatial transformations of chess positions. We explored the following problem: does memory performance depend on whether the piece makes a chess move (A) or a free-form transition (B)? Twenty-five volunteers (twenty-two men and three women, mean age 19.4 years), from beginners to experts, participated in the experiment. As stimuli, sequences (7–15 positions) containing one bishop (1) or two bishops (black and white) (2) were used. Interestingly, both beginners and experts recalled type 1 sequences less well than type 2 sequences. For the beginners, the level of performance at the recall of A1 sequences was lower in comparison with B1 sequences ($p < 0.01$). Conversely, their level of performance in recalling A2 sequences was higher in comparison with B2 sequences ($p < 0.01$). The model we have developed, based on the dependence of error distribution on the distance between the stimulus and the distractor, allows us to assume that the storage of spatial transformations of chess positions is carried out in two ways: the resulting stimuli are stored in relation to the preceding ones for type A sequences; all stimuli are stored independently from each other for type B sequences.

◆ **Red is retained efficiently in human visual working memory**

A Lak, A Borji (School of Cognitive Sciences [SCS], Institute for Studies in Theoretical Physics and Mathematics [IPM], Niavaran, PO Box 19395-5746, Tehran, Iran; e-mail: lak@ipm.ir)

The capacity of human visual working memory is extremely restricted. This limitation requires efficient mechanisms to choose the most relevant features from the environment to be represented in the working memory (Vogel et al, 2005 *Nature* **438** 500–503). Psychological studies in humans have revealed the relevance of red, maybe because this colour is the sign of hazard in nature (Hill and Barton, 2005 *Nature* **435** 293). Here, we aimed to examine the hypothesis that red might be retained more efficiently compared to other colours in visual working memory. On each trial, a sample array consisted of 3, 5, 7, or 9 coloured squares (with the same luminance) was presented for 500 ms. This was followed by a 900 ms blank interval and then 2000 ms presentation of test array consisted of two coloured squares. Observers were asked to select the square with the colour presented in the sample array. The performance of observers for all colours was high for arrays with 3 and 5 items. However, observers showed significantly higher performance for retaining red compared to other colours for arrays with 7 and 9 items. Current study suggests that various colours are retained differentially in working memory, based on their relevance in real world.

◆ **Investigation of the relation between the type of personality and temporal characteristics during the process of recognition**

S Ivanov, P Malysheva¶ (St Petersburg State Electrotechnical University, ul. Prof. Popova 5, 197376 St Petersburg, Russia; ¶ St Petersburg State University, nab. Makarova 6, 199034 St Petersburg, Russia; e-mail: yivanov1@rambler.ru)

The idea of a relation between personal characteristics and psychophysiological reactions in the process of recognition has been expressed before (see Chuprikova, 1995 *Voprosy Psikhologii* number 4, 65–82; Eysenck, 1995 *Voprosy Psikhologii* number 1, 111–131). We tested experimentally this theory and measured minimal response times of extroverts and introverts during a decision process. For this purpose we devised a computer program (S V Ivanov et al, Certificate 2000610885, SPETU, 2000). We used a psychological test to determine extroverts and introverts. The questions were displayed on a monitor screen and the subjects were required to answer “yes” and “no” as quickly as possible and to press a corresponding button. In the first experiment, thirty-eight sportsmen made minimal answers to all short questions and we measured the response times. In this case a correlation with personal characteristics was found. When the questions and answers were long, we have not found such correlation. Thirty-eight sportsmen were tested and the response time varied from 1.6 to 28 s. The response time was 4.6 ± 0.93 s for twenty extroverts and 6.2 ± 0.69 s for eighteen introverts ($\varphi = 2.74$, $p \leq 0.01$, Fischer's criterion).

◆ **Strategy of image examination in early vision**

O V Levashov (Moscow Pedagogical State University, Malaya Pirogovskaya 1, 119992 Moscow, Russia; e-mail: olevashov@mail.ru)

Colour image of a 3-D scene was presented at 100–300 ms and then was replaced by a multi-coloured field of small digits to mask the test image and to code a location of last fixation. Subjects had to name the digit they saw. Twenty-six subjects participated in the experiment. Three groups with different styles of image examination were isolated. (i) ‘Visuals’ perceive images as a whole and reveal a small eye–motor activity. They need 100–200 ms of exposure to understand the total structure of the scene presented. (ii) ‘Logics’ cannot see the image except the nearest fragment (usually high-contrast details). They cannot understand the 3-D structure of the scene presented even at exposures lasting 800–1500 ms. (iii) ‘Inspectors’ immediately perceive a large central part of the test image, notice the main visual features, and make active eye movements to inspect the scene in detail. They often fixate far objects and the horizon. This means they can evaluate the 3-D structure of the scenes for initial fixations. Thus ‘visuals’ have a wide operative field and use holistic strategy of recognition; ‘logics’ have a small operative field and use analytic strategy; ‘inspectors’ occupy an intermediate position.

◆ **Response bias produced by the standard stimulus**

S Fontes, A I Fontes, A Villarino (Facultad de Psicología, Universidad Nacional de Educación a Distancia, Juan del Rosal 10, E 28040 Madrid, Spain; e-mail: sfontes@psi.uned.es)

Villarino et al [1992 *Fechner Day 92, Proceedings of the Eighth Annual Meeting of the International Society for Psychophysics, Stockholm* Eds G Borg, G Neely (Stockholm: Stockholm University—International Society for Psychophysics) pp 211–216] studied the response bias produced by the standard stimulus in the visual and olfactory modalities, observing that this bias is not equally exhibited by all subjects. Our goal was to investigate the bias produced by the standard stimulus at an individual level. We obtained Pearsons product moment correlation between the standard stimulus and the response of the subject. We performed two experiments in the visual modality using the method of magnitude estimation: in one experiment, the distance between two straight lines was estimated; and in the other, line segments were estimated. Our results confirm those of Villarino et al (1992, loco cit.) in the first experiment but not in the second. After estimation of the distance between two straight lines there were individual differences in the bias, but this did not happen after estimation of segments. This difference in the results may be due to the fact that the second experiment is a more typical psychophysical experiment, since the stimulus range is larger than in the experiment on estimation of distances between two straight lines.

◆ **Ratings of differences between pairs of natural images are primarily based on low-level cues**

M To, P G Lovell¶, T Troscianko¶, D J Tolhurst (Department of Physiology, Development and Neuroscience, Physiological Laboratory, University of Cambridge, Downing Street, Cambridge CB2 3EG, UK; ¶ Department of Experimental Psychology, University of Bristol, 12A Priory Road, Bristol BS8 1TU, UK; e-mail: mpst2@cam.ac.uk)

We are investigating how the visual system processes differences between pairs of natural images. Eleven observers viewed 900 pairs of coloured natural images from an extensive database and were asked to rate the perceived difference between each pair. 180 original photos were each paired with 5 variants (either slightly different scenes or edited versions created with image-processing software). The correlation coefficients between the ratings of different observers to the same image pairs ranged from 0.44 to 0.72, and were notably higher than the correlation (0.17 to 0.42) with the predictions of a basic visual-difference predictor model (Párraga et al, 2005 *Perception* 34 Supplement, 155), suggesting a possible role for higher cognitive cues in observers’ ratings. We investigated this possibility by comparing the ratings of seven new observers to 180 of the image pairs, when these were presented upright versus inverted. The correlation coefficients between the upright and inverted ratings ranged from 0.54 to 0.79 (mean = 0.65), compared with coefficients of about 0.75 when observers rated the same image pairs more than once the same way up. For most image pairs, observers seem to make ratings primarily on the basis of low-level visual cues, some of which may not be coded correctly by the basic model.

[Supported by EPSRC/Dstl (ref RG/S56405/01).]

◆ **Cortical brain network for intention-based mentalisation in the perception of animated patterns: An event-related fMRI study**

N Osaka, T Ikeda, M Osaka (Department of Psychology, Graduate School of Letters, Kyoto University, Kyoto 606-8501, Japan; e-mail: osaka@psy.bun.kyoto-u.ac.jp)

We report a neuroimaging study with an event-related fMRI in which eight participants were scanned during watching computer-generated animations that consisted of simple geometrical

shapes, the motion patterns of which strongly evoked intentional mental state attribution (eg Heider and Simmel, 1944 *American Journal of Psychology* **57** 243–249). We also showed the same participants a simple motion, as a control, the pattern of which was likely to evoke less mental state attribution. The degree of intentionality of the animation pattern was controlled on the basis of the rating data from 50 animation patterns in a preliminary experiment. Functional brain imaging data indicated increased activation in association with mental state attribution in superior temporal sulcus (STS), fusiform area (FFA), medial prefrontal cortex (MPFC), and extrastriate cortex. We suggest that these brain regions form a network for processing information about intentions, and speculate that the top–down attentional processes make inference about other people's mental state.

[Supported by grants #16203037 from JSPS and Nissan Science Foundation 2005 to NO.]

◆ **Wish you were here: People's need for affiliation influences their perception of ambiguous point-light walkers**

R M Puca, G Rinkenauer¶, N F Troje§ (University of Tübingen, Friedrichstrasse 21, D 72072 Tübingen, Germany; ¶ Institute for Occupational Physiology, University of Dortmund, Ardeystrasse 67, D 44139 Dortmund, Germany; § Canadian Institute for Advanced Research, Queens University, Kingston, Ontario K7L 3N6, Canada; e-mail: rosa-maria.puca@uni-tuebingen.de)

Point-light walkers are ambiguous stimuli when no explicit depth cues are provided. Recently it has been shown that frontal views of such walkers are more often interpreted as facing towards the viewer than facing away from the viewer (Vanrie et al 2004 *Perception* **33** 547–560). As human walkers are social stimuli, we investigated the influence of social motives on participants' perception. Participants were shown moving point-light figures from 80 different male and female walkers and they had to decide for each walker whether he or she seemed to move towards or away from them. Again moving-towards interpretations were more frequent than moving-away interpretations. This result, however, was qualified by participants' dispositional need for affiliation and their gender. Among women the preference for the towards-interpretation could only be shown when their need for affiliation was high but not when it was low. In contrast, men's need for affiliation had no impact on their perception. High-affiliation women decided more often than high-affiliation men that the walkers moved towards them. The influence of motivation on perception is discussed.

◆ **Penalty kick: When to the decide where to kick**

A Pin, T A Agostini, G Righi, A C G Galmonte (Department of Psychology, University of Trieste, via S Anastasio 12, I 34134 Trieste, Italy; e-mail: pin@psico.units.it)

Experimental sport psychology is an emerging reality in human sciences for a better understanding of how athletes develop mental strategies to optimise their performance. A striker can use two strategies to kick a penalty: to wait for the goal-keeper movement before choosing where to kick the ball, or to decide a priori on the direction to give to the ball. By using visual cues (lights placed behind the goal), fifteen strikers were asked to shoot the ball in a specific region of the goal while the run was already started. The experimental variable was the temporal gap between the visual stimulus and the foot contact against the ball (anticipation: none, 300 ms, and 600 ms before the contact). Results show that, in our conditions, an anticipation of 300 ms is the best temporal gap for improving the performance. On the contrary, a reduction of the performance was observed when the visual stimulus was set on a temporal gap equal to the reaction time of the striker. The method used in our experiments, and the results obtained, underline the possibility of implementing specific training sessions for penalty strikers based on individual strategy aimed to determine the best timing for each athlete.

◆ **Amodal completion of natural objects: Effects of material properties**

S Vrans, T C J de Wit, R van Lier (Nijmegen Institute for Cognition and Information [NICI], Radboud University Nijmegen, PO Box 9104, NL 6500 HE Nijmegen, The Netherlands; e-mail: s.vrans@nici.ru.nl)

To understand how people normally perceive partly occluded objects as wholes, much research has been done with stylistic stimuli. Recent studies found strong preferences for completing the occluded object in accordance with general (global) properties of the stimulus. It was argued that contextual, overall characteristics of the stimulus govern completion. In the case of more veridical stimuli, perceivers' knowledge of material properties could constitute such a contextual factor as well. Therefore, in this study, we measured the perceived form of images of penetrating objects when hardness of their materials might, or might not, conflict. By means of the primed matching paradigm we independently varied the material and shape properties of the two objects

(using slices of cucumbers, metal discs, bricks, and butter) to investigate which objects would be completed. Particularly, after 300 ms of prime duration, differential priming effects were measured for different material combinations. Amodal completion strongly depended on material properties; soft materials did not penetrate hard materials, whereas hard materials could very well penetrate soft materials. We demonstrated that, beside mere shape aspects, material properties also play a role in amodal completion—even at relatively early stages of the completion process.

◆ **Processing visual orientation that is only imagined**

B Bridgeman, S Macramalla (Department of Psychology, University of California, Santa Cruz, 347 Social Sciences 2, Santa Cruz, CA 95064, USA; e-mail: bruceb@ucsc.edu)

Since it is known that imagery affects perception, and perception affects spatial orientation, we might expect imagery to affect spatial orientation. We tested this by measuring reaction times for imagined motion in either a large or a small imagined environment. Each subject imagined either a large or a small environment with a set of landmarks directly in front, to the right (90°), to the left (-90°), or behind the body. The large environment was a field with landmarks several tens of meters distant, while the small environment was an indoor setting with landmarks about 2 m away. Subjects were instructed with a standard computerised voice to imagine turning from one landmark to another, and to respond when the new landmark was imagined directly ahead. Reaction times were about 180 ms longer for the large imagined environment, even though the subject's imagined motion was the same in both cases. We conclude that the path from one landmark to another is confounded with the angular self-rotation in spatial imagery. In a second experiment, subjects required a longer time to complete an imagined rotation after walking with a heavy backpack through a fixed course than walking the same course with an empty backpack.

SPATIOTEMPORAL VISION

◆ **Moving gratings adapt higher spatial frequency channels**

R Azadi, S R Afraz¶ (Ahvaz Jondishapour University of Medical Sciences, PO Box 45-61355, Ahvaz, Iran; ¶ School of Cognitive Sciences, Institute for Studies in Theoretical Physics and Mathematics, Niavaran, PO Box 19395-5746, Tehran, Iran; e-mail: r.azadi@yahoo.com)

The apparent number of a set of moving spots seems greater as their movement speed increases, a phenomenon called motion-induced overestimation (MIO). MIO occurs at much lower temporal rates than the previously investigated phenomenon, frequency doubling. To investigate possible low-level mechanisms behind MIO, we measured the detection contrast threshold for various spatial frequencies after adaptation to a constant-spatial-frequency sine grating (1 cycle deg^{-1}) under two temporal rates (1 and 9 Hz). The results show that as the temporal rate of the adapting grating increases, the maximum spatial-frequency adaptation (measured by means of contrast threshold elevation) occurs at higher spatial frequencies. The amount of shift in the adaptation peak is consistent with the observed increase in the apparent spatial frequency of the moving stimuli due to MIO. This result suggests a low-level mechanism for MIO illusion.

◆ **Contrast adaptation at different loci is expressed distinctively in striate cortical neurons**

N T Dhruv, C Tailby, S H Sokol, N J Majaj, P Lennie (Center for Neural Science, New York University, 4 Washington Place, Room 809, New York, NY 10003, USA; e-mail: ndhruv@cns.nyu.edu)

In the primate, contrast adaptation is evident in the responses of M-cells in the LGN. This must be inherited to some extent by any cortical neuron that draws input from M-cells. Cortical cells also adapt to stimuli that do not cause adaptation in M-cells, suggesting that adaptation can emerge at multiple loci along the visual pathway. We examined whether adaptation at different loci could be revealed through different effects on the contrast gain and response gain of neurons in V1 of anaesthetised macaques. To isolate the influence of adaptation occurring subcortically, we used adapters modulated at temporal frequencies too high to drive cortical neurons, but effective in adapting geniculate cells. To isolate possibly distinct components of cortical adaptation, we used adapters at either preferred or null orientations, modulated at low temporal frequencies that adapted cortical cells but not subcortical ones. The results suggest that contrast adaptation acts: (i) subcortically in a manner that reduces contrast gain only; (ii) in striate cortex via a mechanism that is untuned for orientation and which mostly reduces contrast gain; (iii) in striate cortex via a mechanism that is tuned for orientation and decreases both contrast gain and response gain.

[Supported by NIH grants EY 04440 and EY 13079.]

◆ **Are the details of oriented visual stimuli better resolved when they are horizontal or vertical rather than oblique?**

R S Ivanov, I V Bondar, K A Saltykov, I A Shevelev (Institute of Higher Nervous Activity and Neurophysiology, Russian Academy of Sciences, Butlerova 5a, 117485 Moscow, Russia; e-mail: ivanrost@ihna.ru)

We examined the 'oblique effect'—greater representation in the primary visual cortex of neurons tuned to the vertical and horizontal orientations than to oblique ones. Intrinsic optical signal at the activated cortical columns in area 17 was recorded in nine cats. Animals were anaesthetised and immobilised. The skull was opened above left area 17, and a special recording chamber filled with silicone oil was placed over the cortex. Stimuli were presented in a monocular visual condition 57 cm away from the animal: grids of 8 orientations (in 22.5° steps from 0° to 157.5°) were drifted back and forth in a direction orthogonal to stimulus orientation. The region of interest in cortical maps was determined and single condition maps were further analysed. Different threshold criteria were used for the selection of activated parts of the cortex. The area of activated cortex surface was separately calculated for stimuli with oblique and orthogonal orientations. The 'oblique effect' was not proved in our study: the areas of activation of the cortical columns did not differ statistically for two basic vs oblique orientations. The reason for the difference in electrophysiological and optical data is discussed, as well as the possible role of experimental protocol and of individual visual experiences of different animals.

[Supported by the Russian Foundation for Basic Research (project # 03-04-084).]

◆ **Detection of illusory, stereo-defined, and motion-defined contours is mediated by a common mechanism**

T Sato, S Arai¶, S Kamiya§ (Department of Psychology, Faculty of Letters, [¶ Department of Psychology, Graduate School of Humanities and Sociology], University of Tokyo, 7-3-1 Hongo, Bunkyo-ku, Tokyo 113-0033, Japan; § Intelligent Modeling Laboratory, University of Tokyo, 2-11-16 Yayoi, Bunkyo-ku, Tokyo 113-8656, Japan; e-mail: Lsato@mail.ecc.u-tokyo.ac.jp)

To examine the relationships among the mechanisms for luminance, second-order, and illusory contours, we measured the threshold signal-to-noise ratio for detecting motion-defined contours after adapting to luminance-, motion-, stereo-defined, and illusory contours. We used luminance-modulated dynamic random dots, RDK, and DRDS for luminance-, motion-, and stereo-defined stimuli. Illusory contours were generated by abutting gratings. They all subtended 6 deg × 6 deg (dot size = 6 min of arc), and the field was divided in two by a vertical contour (presentation rate = 0.5). Incoherent dynamic noise dots were superimposed for threshold measurements. Pattern refresh rate was 120 Hz. A dynamic polariser attached to the screen and Polaroid glasses were used for all stimuli to keep the luminance and temporal rate constant. The participants were asked to detect the dividing contour. The stimulus was presented for 200 ms after a 3.5 s adaptation (30 s initial adaptation). We found that adaptation to luminance-defined contours did not affect the detection of motion-defined contours, but that the threshold was elevated by adaptations to motion-defined, stereo-defined, and even to illusory contours. These results indicate that a common mechanism exists for detection of second-order and illusory, ie non-classical, contours but it is separate from that for luminance contours.

[Supported by Grant-in-Aid for Scientific Research to TS from the Ministry of Education, Science, Sports and Culture.]

◆ **Measuring the global-local effect using backward masking and contrast threshold**

W L Slaghuis, M Tsinoğlu, S Johnson (School of Psychology, University of Tasmania, Private Bag 30, Hobart, Tasmania 7001, Australia; e-mail: walter.slaghuis@utas.edu.au)

To date, all studies on the global–local effect (the finding that the global features of an object or scene is processed more rapidly than its local details) have used reaction time as the dependent measure. We investigated whether visual backward masking and contrast thresholds could be used to investigate the global–local effect. In the first two experiments, the global–local effect was measured by the reaction-time method and visual-backward-masking method in the same group of observers. The results of both experiments revealed similar global 'precedence' and 'consistency' effects. In experiment 3 we measured the contrast thresholds for global and local stimuli followed by a masking stimulus, and in experiment 4 we measured global and local stimuli at three target durations (20, 40, 80 ms). The results of both experiments revealed significant global 'precedence' and 'consistency' effects. In addition, the results also revealed that contrast thresholds decreased rapidly with increasing target duration for local stimuli and decreased much more slowly as a function of target duration for global stimuli. Taken together, the findings demonstrate that the measurement of contrast threshold and visual backward masking can be used to investigate the temporal emergence of global and local visual information in vision.

◆ **Organisation of cortical area 21a for simple and complex stimuli: A brain optical imaging study**

C Casanova, M Villeneuve[¶], M Vanni[§], J Roy[#], M Pito (École d'Optométrie [[¶]Département de Physiologie; [§]Département de Sciences Biomédicales], Université de Montréal, 3744 Jean-Brillant, Montréal, Québec H3T 1P1, Canada; [#]École d'Optométrie, Institut de Génie Biomédical, Université de Montréal, and École Polytechnique, Montréal, Québec, Canada; e-mail: christian.casanova@umontreal.ca)

Area 21a is a region of the cat's suprasylvian cortex that receives its principal cortical input from areas 17, 18, and 19 and interacts with the lateral posterior nucleus. On the basis of the functional properties of area 21a cells, it is believed that this area is involved in form processing and constitutes a key component of the temporal processing stream such as area V4 in macaque. Using optical imaging of intrinsic signals, we determined the functional cortical organisation for orientation selectivity to first-order and second-order gratings. A random-dot kinematogram (RDK) consisting of white circular dots on a black background was also used to assess the modular organisation for direction selectivity. Results indicate that orientation selectivity was organised in a modular architecture. Orientation tuning was robust and highly selective but direction selectivity was weak. Orientation maps could be optimally revealed with 0.3 cycle deg⁻¹ spatial frequency. Second-order gratings and RDKs did not reveal any cortical maps. These results provide evidence of a modular organisation for orientation beyond the primary visual cortex, in a higher cortical area of the cat brain. This supports the assumption that area 21a is involved in form processing. However, the nature of this processing appears to be specific to first-order parameters.

[Supported by CIHR and FRSQ to CC]

◆ **Visibility of spatial and temporal blur in dynamic natural scenes**

M Dorr, M Böhme, T Martinetz, K R Gegenfurtner[¶], E Barth (Institute for Neuro- and Bioinformatics, University of Lübeck, Ratzeburger Allee 160, D 23538 Lübeck, Germany; [¶]Department of Psychology, Giessen University, Otto-Behaghel-Strasse 10, D 35394 Giessen, Germany; e-mail: dorr@inb.uni-luebeck.de)

We investigated the visibility of spatial and temporal blur in dynamic natural scenes as a function of retinal eccentricity. We used a gaze-contingent display that allowed us to vary the spatiotemporal frequency content of image sequences under natural viewing conditions. Subjects watched 20 s long video clips of outdoor scenes. Within a ring-shaped region around the point of regard, we applied a local low-pass filter either spatially or temporally with a certain frequency limit. The annulus had a width of 2.5 deg at an eccentricity of 0, 10, 20, or 30 deg. The threshold frequencies were determined in an interleaved staircase procedure where subjects had to indicate whether they had perceived any image degradation. We performed the same experiment with synthetic movies. Pixel intensity was either random (dynamic white noise) or the movie was synthesised from a spatiotemporal Laplacian pyramid with random values (this corresponds to 1/f noise). Spatial thresholds were similar for natural and 1/f movies (8 cycles deg⁻¹ foveally, 2 cycles deg⁻¹ peripherally), but quite different for white noise (11–12 cycles deg⁻¹, constant across eccentricity). Temporal thresholds were similar for white and 1/f noise (25 and 20 frames s⁻¹, constant across eccentricity), but different for natural movies (20 frames s⁻¹ foveally, 5 frames s⁻¹ peripherally).

[Supported by the German Ministry for Research and Education (BMBF) under grant 01IBC01B.]

◆ **Contour coding and structural luminance coding in real-world scene recognition**

J Q Li, J-P Gaillard, M Maurizot[¶], N Portolan[¶], Y Noel (Department of Psychology, University of Rennes, 2 Place de Recteur Henri Le Moal, F 35043 Rennes, France; [¶]Research & Development France Telecom, 4 rue du Clos Courtel, PO Box 91226, F 35512 Cesson Sévigné Cedex, France; e-mail: jingqiang.li@francetelecom.com)

Studies on scene recognition have shown that two kinds of information can be coded and stored during the early stages of low-level cognitive processing of complex scenes. These are contour information and spatial distribution of luminance information. The purpose of this work was to investigate how these two types of information are used by humans to process information in a real-world scene. In our study, the subjects were first shown a 'target image' followed by a 'test image' after which they had to decide in a go/no-go fashion whether it was the same image. The target image could be transformed and belonged to one of these three categories: an original image, a contour image, or a luminance image, whereas the test image was always an original image. In our experiment, two factors were varied: the type of transformation, and the time it took to present the target images. We recorded each subject's answer (true or false)

and reaction time. The results show that the process of recognition of the same image could be based on contour coding; and that the non-recognition of an image could be based on the spatial distribution of luminance.

◆ **A comparison of shape encoding in primate dorsal and ventral visual pathways**

S R Lehigh, V Juneja¶, A B Sereno¶ (Computational Neuroscience Laboratory, The Salk Institute, 10010 North Torrey Pines Road, La Jolla, CA 92037, USA; ¶ Department of Neurobiology and Anatomy, University of Texas Medical School – Houston, 6431 Fannin Street, Houston, TX 77030, USA; e-mail: sidney@salk.edu)

Ventral and dorsal visual pathways perform fundamentally different functions. The former is involved in object recognition, whereas the latter carries out spatial localisation of stimuli and visual guidance of motor actions. Despite the association of the dorsal pathway with spatial vision, shape selectivities have recently been reported in the dorsal stream. We compared shape encoding by neurons in anterior inferotemporal (AIT) cortex, a high-level ventral area, with those in lateral intraparietal cortex (LIP), a high-level dorsal area. Both were tested with simple two-dimensional shapes while the monkey performed a fixation task. We found shape selectivities of individual neurons to be greater in AIT than in LIP. At the neural population level, responses to different shapes were more dissimilar in AIT than in LIP. Both these observations suggest a greater capacity in AIT for making finer shape distinctions during object identification than in LIP. A cluster analysis of the AIT data grouped together similar shapes based on the patterns of neural population responses, while such grouping was indistinct in the LIP data. These differences provide the first neurophysiological evidence that the shape selectivities in the dorsal pathway are independent and not merely the duplication of shape selectivities formed in the ventral pathway.

[Supported by grants from the NIH (R01 MH63340 and R01 MH65492), the National Alliance for Research on Schizophrenia and Depression (NARSAD), and the J S McDonnell Foundation.]

◆ **Effects of band-pass filtering of natural scenes on the BOLD response in V1**

F Schalk, J W Rieger, N Koechy, M Grueschow, H-J Heinze (Department of Neurology II, Otto von Guericke University, Leipzigerstrasse 44, D 39120 Magdeburg, Germany; e-mail: franziska.schalk@web.de)

We investigated the V1 BOLD response to spatially band-limited natural scenes with a constant bandwidth. Eight subjects viewed spatially filtered photos of natural scenes with centre frequencies of 0.42, 1.26, and 3.78 cycles deg^{-1} , and a 1.5 octave bandwidth. In additional conditions, the RMS contrast of the low- and high-resolution images, and an unfiltered photo, were adjusted to match the contrast of the intermediate resolution image. BOLD activation was measured in a balanced blocked design. The images were presented parafoveally to the left and right of fixation while subjects performed an attention-binding task. Intact broad-band scenes elicited the highest BOLD responses in V1. Images with medium resolution elicited responses that were weaker, but still stronger than those produced by the low- or high-resolution images. Contrast matching between filtered images had no effect. Our finding that broadband scenes and scenes with an intermediate resolution elicit the strongest BOLD response when RMS contrast is matched is commensurate with the spatial contrast sensitivity function, and may reflect the proportion of neurons activated in V1. This interpretation is consistent with the frequency distribution of spatial-frequency-tuned cells reported in other species.

◆ **Parallel and cross-orientation threshold facilitation following spatiotemporal adaptation under mesopic viewing conditions**

K Langley, P J Bex¶ (Department of Psychology, University College London, Gower Street, London WC1E 6BT, UK; ¶ Institute of Ophthalmology, University College London, 11 – 43 Bath Street, London EC1V 9EL, UK; e-mail: k.langley@ucl.ac.uk)

The effects of spatiotemporal contrast adaptation on contrast detection for spatial pattern vision were investigated. Four adapting patterns consisting of orientation-filtered noise were presented to subjects who were required to report both the orientation and the position of two similar test signals. Threshold contrast elevations were determined as a function of temporal frequency (0–37 Hz) for parallel/orthogonal adaptor/test conditions and under mesopic/photopic viewing conditions. For parallel adaptation, threshold elevations as a function of the temporal frequency of the test signal were largely U-shaped in photopic conditions, but bandpass functions, peaking around 18 Hz, in mesopic conditions. When fixing the temporal frequency of the test signal but varying the adaptor temporal frequency, threshold elevations were mostly bandpass functions whose peak was centred around 18 Hz in photopic, but 9 Hz in mesopic, viewing conditions. In the mesopic condition, however, we report some evidence for a facilitation in threshold contrast

when adapting to low, but testing with high, temporal frequency signals. For orthogonal adaptation conditions, facilitation in threshold contrast was also observed at high/low adapting temporal frequencies in photopic/mesopic conditions. We interpret our results by using a cascaded model of contrast adaptation, in which the transfer functions of luminance-dependent transient-sustained encoding and sustained decoding processes are jointly adapted by the visual system.

WEDNESDAY

ORAL PRESENTATIONS

ASSOCIATIVE LEARNING IN PERCEPTION (PAVLOV AND PERCEPTION)

- ◆ **Cue recruitment and appearance: The new relevance of ideas from half a century ago**
 B T Backus (Department of Psychology and Institute for Neurological Sciences, University of Pennsylvania, 3401 Walnut Street, C-Wing 302-C, Philadelphia, PA 19104-6228, USA; e-mail: backus@psych.upenn.edu)
 The classical (Pavlovian) conditioning experiment is a simple, flexible paradigm for measuring associative learning. Exploiting it to study perceptual appearance is nontrivial, but recent cue-recruitment experiments (Haijiang et al, 2006 *Proceedings of the National Academy of Sciences of the USA* **103** 483–488) show it is feasible. In a modern theoretical framework, based on Bayesian statistical inference, the importance of classical conditioning is clear: optimal estimation requires using new visual cues if they become available. This framework provides a context for developing new experiments and interpreting results. I argue that a ‘new constructivism’ in perception is now possible, if we are willing to adopt the following views: (i) It is essential to study appearance per se. One can study visual discrimination without any theory of appearance, but under natural conditions, appearance is often the representation used for behaviour and for learning about the world (Brunswik, 1956 *Perception and the Representative Design of Psychological Experiments* (Los Angeles, CA: University of California Press; Barlow, 1990 *Vision Research* **30** 1561–1571). (ii) It is easiest to measure learned changes in appearance when stimuli look different from trial to trial (whether or not they are physically different). (iii) Because learning can occur within multiple representations, it is necessary to think explicitly about the criteria for demonstrating that learning has affected appearance. I attempt to place these ideas in their proper historical perspective. [Supported by National Institutes of Health R01 EY 013988.]

- ◆ **Pavlovian learning today**
 S Siegel, L G Allan (Department of Psychology, Neuroscience, and Behaviour, McMaster University, Hamilton, Ontario L8S 4K1, Canada; e-mail: siegel@mcmaster.ca)
 We are born with reflexes—predictable responses to biologically significant stimuli. We learn to respond additionally to signals for such stimuli: an animal responds to signals for a predator, although, as noted by Pavlov, “it is not the sight and sound of the beast of prey which is itself harmful to the smaller animal, but its teeth and claws”. Pavlovian conditioning, the systematic study of such responding to signals, is accomplished by pairing a neutral conditional stimulus (CS) with a biologically significant unconditional stimulus (UCS). The UCS reflexively (ie ‘unconditionally’) elicits some response—the ‘unconditional response’. Following CS–UCS pairings (ie conditional on such pairings), the CS elicits a new response, which is termed the ‘conditional response’ (CR). Recently, investigators have studied the relationship between CR acquisition and CS/UCS contingency, characteristics of particularly effective CSs and UCSs, and the allocation of learning to each of several simultaneously occurring CSs that signal a single UCS. Understanding Pavlovian conditioning is crucial for understanding many seemingly complex phenomena: judgments of correlational relationships between stimuli (eg is an allergic reaction especially likely to occur after eating a particular food?), logical reasoning (eg transitive inference), physiological regulation (eg homeostatic adjustments), and perceptual phenomena (eg contingent aftereffects). [Supported by NSERC, NIH.]

- ◆ **Changes in stimulus appearance mediating abrupt improvements in perceptual tasks**
 N Rubin, K Ludmer¶, Y Dudai¶ (Center for Neural Science, New York University, 4 Washington Place, New York, NY 10003, USA; ¶ Weizmann Institute of Science, IL 76100 Rehovot, Israel; Nava.Rubin@nyu.edu)
 We present behavioral and fMRI results from two paradigms where abrupt improvements in performance co-occurred with changes in stimulus appearance. The first paradigm used brief, masked Kanizsa-type figures with the pacmen inducers slightly rotated, causing the (illusory) edges to appear curved. Initially observers do not perceive the illusory surfaces and base their responses on the rotation of the local inducers, yielding poor performance. After exposure to a few (1–3) trials with more salient illusory surfaces, observers began perceiving illusory surfaces also in the very same stimuli where previously they saw only the local inducers. Basing responses on the (illusory) curvature of the perceptually completed edges boosted performance dramatically. The second paradigm used camouflage images, where an abrupt figure–ground reorganisation is concomitant with sudden recognition of a previously unseen underlying object. We created many camouflage images by blurring + binarising real-world images, and performed whole-head fMRI scans while observers viewed the images for the first time and experienced perceptual transitions, either

spontaneously or induced by a visual cue (the original). Testing a week later which images were still remembered, we found that images that produced more temporal and amygdala activation during induced learning were more likely to show long-term retention.

◆ **Associative learning in cortical visual area MT of macaque monkeys**

A Schlack, T D Albright (HHMI/Systems Neurobiology Laboratories, Salk Institute, 10010 N Torrey Pines Road, La Jolla, CA 92037, USA; e-mail: anja@salk.edu)

Associative learning is frequently thought of as a high-level process. We sought to determine whether associative learning-induced neuronal plasticity is limited to high-level visual processing stages, or whether it is a more general property that could occur also in earlier brain areas. To achieve this goal, we trained monkeys to behaviourally associate naturally effective stimuli for neurons in area MT (translatory motions) with arbitrary non-effective stimuli (static 2-D patterns). We hypothesised that learning of the behavioural association would be paralleled by the emergence of selective neuronal responses to the static stimuli. We recorded from MT neurons before training began and, after training was complete, to a criterion of 80% correct performance. Before training, only 4% of the neurons showed selective responsiveness to the static stimuli. After training, this percentage increased to 19%. Remarkably, the preferred static stimulus for a given neuron tended to be the one that the monkey had learned to associate with the preferred direction of motion for that neuron. This result was highly significant over the population of neurons recorded ($p < 0.001$). We conclude that stimulus selectivities of many neurons in area MT, a relatively early visual processing stage, are plastic and selectively modifiable by associative learning. [Supported by Howard Hughes Medical Institute, Emmy Noether Program (DFG).]

◆ **Associative learning in perception: The role of temporal correlation in establishing transform-invariant representations of objects**

G M Wallis (School of Human Movement Studies, University of Queensland, Brisbane, QLD 4072, Australia; e-mail: gwallis@hms.uq.edu.au)

The view-based approach to object recognition postulates that objects are stored as a series of associated views. Although representation of these views as combinations of 2-D features allows generalisation to similar views, it remains unclear how very different views might be associated together to allow recognition over larger changes in appearance. One cue present in the real world, other than spatial similarity, is that we usually experience different objects in temporally constrained, coherent order, and not as randomly ordered snapshots. Drawing on evidence from neurophysiological, behavioural, and neural network based simulations, this presentation describes how the association of views on the basis of temporal as well as spatial correlations is both theoretically advantageous and biologically plausible. In particular, the talk focuses on a number of behavioural experiments in my laboratory and others in which recognition performance is seen to be affected by exposure to temporal sequences of specific object views. Experiments involving transformations such as depth rotation, frontoparallel planar rotation and illumination are described. Overall the work supports the idea that temporal association can and does play a pivotal role in setting up representations of objects.

[Supported by Australian Research Council and Max Planck Society.]

◆ **Learning effects in figure – ground perception: The importance of indirect measures**

M A Peterson (Department of Psychology and Cognitive Science Program, University of Arizona, 1503 East University Blvd, Tucson, AZ 85721, USA; e-mail: mapeters@u.arizona.edu)

Ever since the Gestalt revolution it has been debated whether past experience can enter into perceptual decisions regarding figure–ground assignment, or whether it necessarily operates post-perceptually. A variety of direct and indirect measures were used to show that even a single experience with a novel figure creates a memory of where the figure lies with respect to the bounding edge, such that the next time the observer encounters the edge (or a portion of it) a memory of where the figure lay on the first exposure either competes or cooperates with other configural cues, depending on their arrangement. Importantly, the learned configuration does not always dominate other figural cues; when it does not, its participation in perceptual decisions is evident in indirect behavioural measures and psychophysiological measures.

◆ **Pavlov meets Posner: Associative learning and the deployment of attention**

Á Kristjánsson (Department of Social Sciences, University of Iceland, Oddi v. Sturlugölu, 107 Reykjavik, Iceland; e-mail: ak@hi.is)

How does the way things look depend on the deployment of attention? Associative learning could affect appearance by causing attentional resources to be allocated to one part of an object or another, as when one attends to one corner of a Necker cube and thereby brings it nearer, or by controlling what information makes it into the system to participate in the building of the percept.

Striking examples of the latter include blindness to 'obvious' stimulus features when attention is directed elsewhere [eg Mack and Rock, 1998 *Inattentional Blindness* (Cambridge, MA: MIT Press)]. Furthermore, appearance must often be constructed under conditions where the information from the stimulus that is available to the perceiver is limited by his capacity to take in information. In those cases, conditioning that leads to differential deployment of attention might have a significant effect on appearance. I review studies that suggest that attention shifts, even very fast or transient, can be more efficient following repeated coupling of a target with a certain stimulus feature on a cue, allowing better discrimination performance as well as more efficient eye movements to behaviourally important regions. Other studies that address how learning in attention shifts can alter visual appearance are also discussed. [Supported by Human Frontiers Science Program; Harvard University; University of Iceland.]

◆ Learning a new prior: Light from above

W J Adams, E W Graf, M O Ernst¶ (School of Psychology, University of Southampton, Shackleton Building, Highfield, Southampton SO17 1BJ, UK; ¶ Computational Psychophysics Department, Max Planck Institute for Biological Cybernetics, Spemannstrasse 38, D 72076 Tübingen, Germany; e-mail: w.adams@soton.ac.uk)

To interpret complex and ambiguous visual input, the visual system uses prior knowledge, or assumptions about the world. These 'priors' could be hard-wired, or learnt in response to statistical regularities in the environment. Here, we consider the 'light from above' prior used by the visual system to extract shape from shading. Observers viewed monocular disks with shading gradients at various orientations. Reported shape (convex or concave) as a function of stimulus orientation was used to recover each observer's assumed light position. During training, observers also 'touched' the disks. The haptic (felt) shape of the training stimuli was consistent with a light source shifted by $\pm 30^\circ$ from the observer's original assumed light position. After training, observers again judged the stimulus shape from purely visual information. Additionally, observers made lightness judgments of a Mach-card type stimulus, before and after haptic training with the concave/convex disk stimuli. Initially, our observers assumed a light position that was roughly overhead. However, after haptic feedback, observers learned to use a shifted light direction for their prior. Importantly, this learning was not specific to the trained task, but generalised such that it affected visual perception in a separate lightness judgment task.

[Supported by the Wellcome Trust (GR069717MA)]

◆ Failures of visual constancies due to erroneous cue recruitment?

L T Maloney, Y X Ho, M S Landy (Department of Psychology and Center for Neural Science, New York University, 6 Washington Place, 8th Floor, New York, NY 10003, USA; e-mail: ltml@nyu.edu)

Many visual constancies are subject to errors that are systematic, reproducible, and puzzling. We propose that these errors may be the result of erroneous cue recruitment. We examined visual estimation of surface roughness using irregular 3-D surfaces rendered under a mixture of diffuse lighting and a punctate source (Ho et al, 2006 *Journal of Vision* 6 634–648). We varied the angle between the plane containing the surface texture and the direction to the punctate source. All observers perceived surfaces to be markedly rougher with decreasing illuminant angle, a systematic failure of 'roughness constancy'. We identified four novel cues that are valid cues to roughness under any single lighting condition, but that are not invariant across changes in lighting condition. We modeled observers' deviations from constancy as a linear combination of these 'pseudo-cues' and found that they accounted for a substantial amount of observers' deviations. We conjecture that pseudo-cues arise as a pathology of cue recruitment: if most comparisons of haptic and visual roughness take place within a single lighting context, then the observed failures of roughness constancy suggest that the visual system is only guilty of over-generalisation of a learned cue beyond its range of applicability.

[Supported by NIH/NEI EY08266.]

◆ Bayesian model-learning and the emergence of visual features and rules

J Fiser, R N Aslin¶, G Orbán§, M Lengyel# (Center for Complex Systems and Department of Psychology, Brandeis University, Waltham, MA 02454, USA; ¶ Department of Brain and Cognitive Sciences and Center for Visual Science, University of Rochester, Rochester, NY 14627 USA; § Collegium Budapest Institute for Advanced Study, 2 Szentháromság utca, H 1014 Budapest, Hungary; # Gatsby Computational Neuroscience Unit, University College London, 17 Queen Square, London WC1N 3AR, UK; e-mail: fiser@brandeis.edu)

Based on our human experimental and modeling work in the last couple of years, in this talk we argue for four related points. First, we suggest that humans develop internal visual representations by incremental learning of the co-occurrence and predictability of visual elements. Second, we present evidence that despite this statistics-based learning, humans do not encode the full

second-order correlational structure of the scene. Rather, they learn a sufficient representation of the underlying independent causes generating the scene, and this strategy naturally leads to the emergence of chunking and some of the basic Gestalt rules of perception. Third, we show that these learning processes can be well captured within the framework of Bayesian model-learning using sigmoid belief networks. This learning scheme seeks out the simplest model of the scene and shifts to more complex models only when it is warranted by additional experience. Fourth, we point out that the same model-learning framework has been shown to be superior to previous associative models in explaining aspects of configural learning in animals and thus it provides a natural link between learning of visual representations and classical conditioning. [Supported by IST-FET-1940, NIH HD-37082, Gatsby Charitable Foundation.]

THE CONE/ROD DICHOTOMY: MOLECULES AND CELL MORPHOLOGY

◆ Difference in molecular properties between rod and cone visual pigments

Y Shichida (Department of Biophysics, Graduate School of Science, Kyoto University and Core Research for Evolutional Science and Technology (CREST), Japan Science and Technology Agency (JST), Kyoto 606-8502, Japan; e-mail: shichida@vision-kyoto-u.jp)

Most vertebrates have two types of photoreceptor cells, rods and cones, which are responsible for twilight (scotopic) and daylight (photopic) vision, respectively. Rods are more sensitive to light than cones, whereas cones display rapid photoresponse and rapid adaptation compared to rods. To obtain insights into the difference in the molecular mechanism(s) of the photoresponses between rods and cones, the molecular properties of rod and cone visual pigments have been investigated, showing that cone pigments exhibit faster pigment regeneration and faster decay of meta-II and meta-III intermediates than the rod pigments, rhodopsin (Shichida et al, 1994 *Biochemistry* **33** 9040–9044). Mutagenesis experiments have revealed that the amino acid residues at position 122 and 189 in the opsin are the determinants for these differences (Imai et al, 1997 *Proceedings of the National Academy of Sciences of the USA* **94** 2322–2326; Kuwayama et al, 2002 *Biochemistry* **41** 15245–15252). To study the relationship between the molecular properties of visual pigments and the physiology of photoreceptor cells, we have generated knock-in mice in which rod visual pigment (rhodopsin) was replaced by the mouse green-sensitive cone pigments (mouse green).

◆ Ancient vertebrate photoreceptors: The evolution and function of rods and cones

S P Collin, D M Hunt¶, W L Davies¶, I C Potter§, H J Bailes, N S Hart, A E O Trezise (School of Biomedical Sciences, University of Queensland, Brisbane, QLD 4072, Australia; ¶ University College London Institute of Ophthalmology, 11–43 Bath Street, London EC1V 9EL, UK; § School of Biological Sciences and Biotechnology, Murdoch University, Murdoch, WA 6150, Australia; e-mail: s.collin@uq.edu.au)

Lampreys (*Agnatha*), sharks and rays (*Elasmobranchii*), and lungfish (*Dipnoi*) represent key stages in vertebrate evolution and can provide unique insights into the origins of rod-based (scotopic) and cone-based (photopic) photoreception. Employing a multidisciplinary anatomical, electrophysiological and molecular approach, we present evidence for the characterisation of receptor types and their function in the context of their visual ecology in a range of early vertebrates. The southern-hemisphere lamprey *Geotria australis* possesses 5 types of photoreceptor (all cones), many of which contain coloured intracellular filters. The shovelnose ray *Rhinobatos typus* possesses 4 types of photoreceptor (3 cones and a rod), and the Australian lungfish *Neoceratodus forsteri* possesses 5 types of photoreceptor (4 cones and a rod). Each technical approach to characterising rods and cones provides a different (sometimes ambiguous) interpretation. Some evidence suggests that the lampreys may possess rod/cone hybrids. Phylogenetic analysis of the opsin genes in lampreys suggests that the Rh1 (rod) opsin evolved after the divergence of the jawless (agnathan) fishes from the jawed (gnathostomatous) vertebrates, indicating ancestral photoreception was based on a cone-based (photopic) visual system. Characterisation of phototransduction genes, photopigment regeneration rates, and electrophysiological analyses of function holds the key to tracing the origins of duplex vision in vertebrates. [Supported by the Australian Research Council.]

◆ Divergent evolution and adaptation in cone visual pigments: Mix and match colour vision in African cichlid fish

J K Bowmaker, J W L Parry, T Spady¶, O Seehausen§, D M Hunt#, K L Carleton¶ (Division of Visual Science [¶ Division of Molecular Genetics], Institute of Ophthalmology, University College London, Bath Street, London EC1V 9EL, UK; ¶ Hubbard Center for Genome Studies and Department of Zoology, University of New Hampshire, Durham, NH 03824, USA; § Aquatic Ecology and Macroevolution, Institute of Zoology, Department of Biology, University of Bern, CH 3012 Bern, Switzerland; e-mail: j.bowmaker@ucl.ac.uk)

Cichlid fish of the African Great Lakes are renowned for their diversity and offer a unique opportunity to study adaptive changes in rapidly evolving species flocks. Since these fish use

visual communication for mate choice and males display an impressive array of colour patterns, differences in visual sensitivities could greatly influence or even drive speciation of cichlids. By combining microspectrophotometry (MSP) of isolated cones, sequencing of opsin genes and spectral analysis of recombinant pigments, we have established the cone complements of a number of species of Malawi and Victoria cichlids. MSP demonstrated that each of these species predominately expresses three cone pigments, although these differ between species to give spectrally different cone complements. In total, seven spectral classes of cone were identified and confirmed by opsin gene sequencing, expression, and in-vitro reconstitution. The gene complement consists of a long-wave-sensitive (LWS), three spectrally distinct green-sensitive (RH2A α , RH2A β , RH2B), a blue-sensitive (SWS2A), a violet-sensitive (SWS2B), and an ultraviolet-sensitive (SWS1) gene. African cichlids determine their spectral sensitivity by differential expression of only three of the seven cone opsin genes. Victoria cichlids express only a long wavelength set, whereas within Malawi species at least three different combinations of cone opsin genes have been identified. [Supported by a grant from the Leverhulme Trust to JKB and DMH and by a National Science Foundation grant to KLC (IBN-0131285).]

◆ **Rods and cones: Protein-ligand interactions**

R K Crouch, M Kono (Department of Ophthalmology, Medical University of South Carolina, Charleston, SC 29425, USA; e-mail: crouchrk@musc.edu)

The opsins of cone and rod retinal photoreceptors share much structural homogeneity and are all G-protein coupled receptors. These opsins all use a common ligand, 11-cis retinal, as a reverse agonist to lock the proteins into their inactive conformation. This ligand also acts as a chromophore, as, when the ligand is bound to the protein, these proteins then absorb at various wavelengths in the UV and visible regions. However, the opsins, whether a rod or cone opsin, have quite different and specific interactions with their ligands which have a profound influence on their respective function. We have used analogues of retinal to probe these interactions and to examine the consequent effects on the function of these pigments. We find that the ability to form a pigment, the stability of the protein–ligand interaction, the rate of transduction activation, and the stability of the various photointermediates are all affected by the structure of the ligand and are variable depending on the opsin tested. The 9-methyl and 13-methyl groups on the retinal are particularly critical in determining these interactions. [Supported by NIH grants EY04939, EY14793 and EY13748, and Research to Prevent Blindness.]

◆ **Turning cones off: The role of the 9-methyl group of retinal**

M C Cornwall (Department of Physiology and Biophysics, Boston University School of Medicine, 715 Albany Street, Boston, MA 02118, USA; e-mail: cornwall@bu.edu)

The mechanisms underlying the rapid rate of flash response recovery in cone photoreceptors following exposure to bright light were investigated. Electrophysiological recordings were made from salamander cones containing native pigment, either 11-cis retinal or 11-cis 9-demethyl retinal. Rates of flash response recovery and guanylyl cyclase (GC) rate were compared. Dim flash responses exhibited no significant differences in kinetics when elicited in either red cones containing 11-cis retinal or 11-cis 9-demethyl retinal. However, following exposure to bright light (> 0.3% bleach), red cones containing 11-cis 9-demethyl retinal recovered flash response amplitude and GC rates significantly more slowly than red cones containing 11-cis retinal. This finding is consistent with previous results demonstrating that red cone opsins expressed in vitro lacking the 9-methyl group exhibit prolonged activation due to slowed Meta II decay. It is suggested that multiple mechanisms regulate the recovery of responsiveness in red cones following exposure to light. Recovery of dim flash responses is regulated by phosphorylation and arrestin binding. However, at high light intensities regulation occurs by mechanisms involving Meta II decay rate. In red cones, recovery depends critically on the 9-methyl group on retinal. These findings provide a partial explanation for rapid rates at which cones recover sensitivity following bleaching.

◆ **Functional differences between rods and cones: Kinetics, sensitivity, noise, operating range, and recovery from bleaches**

T D Lamb, E N Pugh Jr¶ (Division of Neuroscience, John Curtin School of Medical Research, and ARC Centre of Excellence in Vision Science, Australian National University, Canberra, ACT 0200, Australia; ¶ F M Kirby Centre for Molecular Ophthalmology, Department of Ophthalmology, University of Pennsylvania, Philadelphia, PA 19104-6069, USA; e-mail: Trevor.Lamb@anu.edu.au)

Cones are specialised for rapid detection of visual stimuli, and can function at arbitrarily high intensities. Rods, in contrast, have slower responses and are restricted to operating at low intensities, but, importantly, they are able to reliably detect individual photons. The rod manages to

achieve a 'dark light' at least 10 000-fold lower than in a cone, and this difference is crucial to the ability of the visual system to function at extremely low light levels. The low dark light arises in part from the much greater thermal stability of the rhodopsin molecule, in comparison with the cone visual pigment, which exhibits a significant tendency to dissociate into opsin and chromophore. The faster response kinetics of the cone is associated with faster inactivation reactions: activated visual pigment is inactivated about 20-fold faster than in rods, and the life-time of the activated G-protein/PDE is correspondingly shorter. Yet the gain of activation is quite similar in rods and cones. Recovery of circulating current upon extinction of intense illumination occurs at least 10 000-fold faster in cones than in rods. The cone transduction machinery appears almost immune to the presence of bleaching products. The basis and the significance of these differences will be discussed.

[Supported by Australian Research Council grants FF0344672 and CE0561903 (TDL), and NIH EY-02660 and Jules & Doris Stein Research to Prevent Blindness Professorship (ENP).]

- ◆ **Functional properties of mouse M- and S-cones determined from single-cell recordings**
S S Nikonov, E N Pugh Jr (F M Kirby Center for Molecular Ophthalmology, Department of Ophthalmology, University of Pennsylvania, Philadelphia, PA 19104-6069, USA;
e-mail: sergein@mail.med.upenn.edu)

Circulating currents of WT mouse cones were recorded with suction pipettes at 20 Hz bandwidth from cell perinuclear regions at 35–37 °C. Rod currents were suppressed with 500 nm light. All cones from the ventral retina ($n = 9$) and most cones recorded from undetermined locations (12/16) were S-pigment dominant, with maximal sensitivity at 360 nm and a secondary mode ($\sim 2\% - 10\%$ of maxima) at 510 nm, the maximum of the cone M-pigment. Cones from the dorsal retina ($n = 7$) were M-dominant with S- to M-sensitivity ratio $\sim 20\%$. S- and M-cones had similar kinetics and flash-sensitivity (M-cones being slightly faster and less sensitive) with response time to peak ~ 70 ms, recovery dominant time constant ~ 70 ms, and half-saturating flash intensity $\sim 3100 - 7700$ photons μm^{-2} . The kinetics of S- and M-responses of individual cones were indistinguishable. Step sensitivity corrected for pigment bleaching was $\sim 130\,000$ photons $\mu\text{m}^{-2} \text{ s}^{-1}$ for both cell types. Circulating current was little affected by M-pigment bleaching (up to 99%). We conclude that apparent differences in kinetics between S- and M-dominant cones may be explained by the effect of rod-suppressing background. Pigment bleaching has little effect on the cone current and may allow cones to escape saturation in bright light.

[Supported by NIH-EY-02660, RPB Foundation.]

- ◆ **Human cone light adaptation linked to molecular mechanisms in photoreceptors**
A Stockman, M Langendörfer, L T Sharpe (Institute of Ophthalmology, University College London, 11–43 Bath Street, London EC1V 9EL, UK; e-mail: a.stockman@ucl.ac.uk)

We have characterised light adaptation under conditions that isolate either M or S cones by measuring temporal sensitivities and phase delays as a function of adaptation level. This combination of data provides a more complete characterisation of light adaptation than is possible with sensitivity measures alone. The same simple model accounts for adaptation of both cone types. At low to moderate levels, the primary adaptation mechanism is a quickening of the temporal response and thus a shortening of the integration time as the level increases. Surprisingly, a secondary mechanism is revealed that increases the overall sensitivity with rising level, which thus counterintuitively opposes the sensitivity losses caused by the primary mechanism. Together, these mechanisms maintain Weber's law at low frequencies, but cause a relative increase in sensitivity at higher frequencies. At high levels, there is an overall decrease in sensitivity across all temporal frequencies. Each stage of the model can be linked to molecular processes within the photoreceptor: the shortening time constants to increases in the rates of decay of active and messenger molecules, the unexpectedly increasing sensitivity to increased rates of molecular re-synthesis and changes in channel sensitivity; and the decreasing sensitivity at high levels to photopigment bleaching. Comparisons are made with rod light adaptation

[Supported by the Wellcome Trust.]

- ◆ **Time scale and size of photoresponses: Rods, cones, and visual function in different animals**
K K Donner (Department of Biological and Environmental Sciences, University of Helsinki, PO Box 65 (Viikinkaari 1), FI 00014 Helsinki, Finland; e-mail: kristian.donner@helsinki.fi)
The 'universal vertebrate phototransduction cascade' in the dark-adapted state is set to different operating points with respect to the time scale and size of the single-photon response: in rods compared with cones and in different animal species. While explanations may invoke different properties of the different isoforms of all the proteins involved in phototransduction, a parsimonious research approach would be to factor out possible invariant properties first, and appeal to

specific molecular adaptations only when simple explanations fail. I discuss how far differences in dark-adapted photoresponses can be explained by differences in visual-pigment-related 'dark light', body temperature, and cell morphology, and relate this to requirements on visual function (time scale and sensitivity) in different cases.

[Supported by Academy of Finland # 206221.]

◆ **Why rods are rods, and cones are cones**

V I Govardovskii (Institute for Evolutionary Physiology and Biochemistry, Russian Academy of Sciences, pr. Toreza 44, 194223 St Petersburg, Russia; e-mail: vgov@mailbox.alkor.ru)

Molecular adaptations that tune photoreceptor cells for a higher sensitivity in rods vs the speed of reaction in cones are now under scrutiny. However, less attention is paid to basic morphological distinctions between rods and cones whose relationship with functional properties of photoreceptors is less obvious. The ultrastructural difference between cone and rod outer segments is plausibly related to faster timing of cone photoresponse. Continuous invaginations of the plasma membrane in cones, compared to rod disks, result in higher surface-to-volume ratio. This accelerates Ca^{2+} turnover thus increasing the speed of the calcium feedback. The most conspicuous difference, that in the cell shape, is apparently related to different optical properties of the two types of photoreceptors. Theoretical considerations and the study of properly scaled microwave models show that the conical shape of the cell and, more efficiently, refracting structures like oil drops, sharpen the angular selectivity of cones. Contrary to the general belief, these structures do not improve the sensitivity of cones, but rather enhance the quality of the image by increasing depth of focus and reducing sensitivity to stray light. The evolutionary strategy of tuning the cell shape to correspond to its function is discussed, on the basis of so-called transmuted photoreceptors. [Supported by Russian Foundation for Basic Research grant 06-04-48914-a.]

SOCIAL PERCEPTION AND BIOLOGICAL MOTION: BRAIN IMAGING PERSPECTIVES

◆ **Social perception, biological motion, and brain connectivity: Brain imaging and development**

M Pavlova (Developmental Cognitive and Social Neuroscience Unit, Department of Paediatric Neurology and Child Development, Children's Hospital, University of Tübingen, Germany, Hoppe-Seyler-Strasse 1, D 72076 Tübingen, Germany; e-mail: marina.pavlova@uni-tuebingen.de)

Perception and understanding of intentions and dispositions of others is an essential ingredient of adaptive daily-life social behaviour. Bodily movements help to improve our social communication by means of non-verbal information about social properties. Observers can discriminate between deceptive and true intentions conveyed by body dynamics, and true information is precisely detected despite deceptive endeavours. However, the perceived dynamics of static images also enables emotional attribution (Pavlova et al, 2005 *Perception* **34** 1107–1116). The tremendous advance in brain imaging that was made in the last years offers new research perspectives in social cognition. Brain imaging data in humans, single-cell recording in the macaque monkey, and neuropsychological studies point to the existence of distributed networks that reveal social attributes through body dynamics. The right superior temporal sulcus, 'social brain' region, is repeatedly reported to be a substantial part of this network. By using clinical models of abnormal development, namely patients with early periventricular lesions (Pavlova et al, 2006 *Annals of Neurology* **59** 415–419; Pavlova et al, 2006 *Neuropsychologia* **44** 586–593) and autistic spectrum disorders, I argue that the structural and functional brain connectivity is of immense importance for proper functioning of the networks underlying visual social perception.

[Supported by DFG, HFSP.O.]

◆ **Brain mechanisms for visually perceiving the actions and intentions of others: Lessons from autism and typical development**

K A Pelphrey (Department of Psychological and Brain Sciences, Duke University, 9 Flowers Drive, Durham, NC 27708-0086, USA; e-mail: kevin.pelphrey@duke.edu)

Social perception, the ability to evaluate the actions and intentions of others on the basis of biological motion cues (eg eye gaze, body posture, and facial expressions), constitutes an advanced perceptual skill set necessary for social success. Specialised brain systems may have evolved that are critical for different aspects of social perception. Several candidate regions thought to comprise the social brain have been identified, including the fusiform face area for face perception, the posterior superior temporal sulcus for the perception of biological motion and the visual analysis of the actions and intentions of others, and the amygdala and ventral frontal regions for the perception of emotional expressions. My laboratory has been investigating the properties of these brain regions using functional magnetic resonance imaging (fMRI) in typically developing children and adults as well as in children and adults with autism. I describe

our recent studies in three parts; (i) I focus first upon functional neuroimaging studies of social perception in typically developing adults; (ii) I discuss a recent study of the neural basis of eye gaze processing deficits in people with autism; (iii) I describe functional neuroimaging studies of the neurobiological basis of social perception development in children.

[Supported by the National Institute of Mental Health Career Development Award.]

◆ **Social perception from static and dynamic visual information**

D I Perrett, D Xiao, T Jellema, N Barraclough, M W Oram (School of Psychology,

University of St Andrews, St Andrews KY16 9JP, Scotland, UK; e-mail: dp@st-and.ac.uk)

Social cognition relies on interpreting the 'state' of others. Shape, texture, and colour cues are available from the face to drive social cognition. Within the temporal cortex, colour modulates responses of 70% of cells tuned to the form of faces. For human perception, colour influences perception of identity, attractiveness, and health. Face colour coded by cells, may therefore shape social cognition. For an agent, the direction of attention and movement relative to objects allow the agent's behaviour to be coded as goal-directed. Extrapolation from visible body movements can support inferences when the action becomes occluded from sight. For example, one can infer the continued presence of a person hidden behind a screen if one sees the person walk there but not re-emerge. Moreover, intentions can be inferred if the person's reappearance does not occur when predicted from their trajectory before occlusion. Information about likely future or prior body movements can also be 'implied' from postures visible at specific moments. It is proposed that associative learning mechanisms relate available visual cues to action outcomes and social cognition. In this scheme, social cognition becomes a process of statistical inference about likely behaviour and the attributes of others from sensory cues.

◆ **Combining results from fMRI and voxel-based lesion-mapping to study biological motion processing**

A P Saygin (Institute for Cognitive Neuroscience and Wellcome Department of Imaging

Neuroscience, University College London, 17 Queen Square, London WC1N 3AR, UK;

also Department of Cognitive Science and Center for Research in Language, University of California San Diego, 9500 Gilman Drive, La Jolla, CA 92093, USA;

e-mail: saygin@crl.ucsd.edu)

Two complementary neuroimaging methods have been used to obtain a more complete picture of the neural circuitry underlying biological motion perception: fMRI with neurologically healthy adults, and structural imaging and computational lesion analyses with focal brain injury patients. In the fMRI study, twelve participants viewed biological motion, scrambled biological motion, or static point-light stimuli. The comparison of biological motion to scrambled motion revealed bilateral activation in lateral temporal and inferior frontal cortex—a network involved in perceiving the actions and intentions of others. In the neuropsychological study, forty-two left-hemisphere patients, seven right-hemisphere patients, and eighteen controls discriminated biological motion from scrambled biological motion in the presence of a variable number of occluding noise dots. A threshold was estimated adaptively. Both left-lesioned and right-lesioned patients performed significantly worse than controls—suggesting that biological motion processing is not strongly lateralised (cf bilateral activation in our fMRI results). Voxel-based lesion analyses revealed that damage to superior temporal and inferior frontal regions were associated with deficits in this task, confirming the importance of these areas for biological motion processing. Thus, this network appears to be both involved in, and necessary for, normal biological motion processing.

[Supported by NIDCD R01 DC00216 and NSF BCS 0224321.]

◆ **Visual processing of speech biological motion**

P Servos, K Munhall ¶ (Department of Psychology, Wilfrid Laurier University, Waterloo,

Ontario N2L 3C5, Canada; ¶ Departments of Psychology and Otolaryngology, Humphrey

Hall, Queen's University, 62 Arch Street, Kingston, Ontario K7L 3N6, Canada;

e-mail: pservos@wlu.ca)

Speech perception can involve visual as well as auditory information processing. For example, under degraded listening conditions, individuals take advantage of visual speech. Much of this visually intelligible phonetic information is dynamic in nature. Visual displays consisting of speech biological motion stimuli enable subjects to identify more words when the auditory speech is embedded in noise relative to their performance in an auditory-only condition. In contrast, such subjects report fewer words relative to the auditory-only condition when incongruent point-light displays are paired with the auditory signal. We used fMRI to investigate whether congruent and incongruent audiovisual speech would modulate cortical responses when subjects performed audiovisual speech integration tasks in which the visual stream consisted only of

biological motion stimuli. As in previous work, we observed activity within the left superior temporal gyrus (STG) during silent speech biological motion perception. Sound also modulated STG activation during speech biological motion. Neural responses in area STG during congruent audiovisual speech were approximately 1.7 times higher than those observed during incongruent audiovisual speech. Although sound also modulated speech biological motion responses in the supplementary motor area, the neural responses during congruent and incongruent speech biological motion perception were similar in this area.

NEUROPHYSIOLOGY OF PRIMARY VISUAL CORTX AND PERCEPTION

- ◆ **The 'blind spot' interferes with the discrimination of the curvature of illusory contours**
M Maertens, S Pollmann (Abteilung für Allgemeine Psychologie, Institut für Psychologie II, Otto von Guericke University, Universitätsplatz 2, D 39016 Magdeburg, Germany; e-mail: marianne.maertens@nyu.edu)

We are able to perceive crisp bounding contours even in the absence of luminance-defined borders as in visual illusions like the Kanizsa figure. It is important to understand the neural processes involved in these artificial visual experiences, since they might tell us how we perceive coherent objects in the natural environment. Sensitivity to illusory stimuli has been observed already for neurons in the primary visual cortex (V1). Here we show that it is in fact the activity of V1 neurons which is obligatory to perceive an illusory contour. We presented illusory contours across the portion of the visual field corresponding to the physiological 'blind spot'. Four observers were extensively trained and asked to discriminate fine curvature differences in these illusory contours. A distinct performance drop was observed when illusory contours traversed the blind spot compared to the 'normal' contralateral visual field at the same eccentricity. We attribute this specific performance deficit to the failure to build up a representation of the illusory contour in the absence of a cortical representation of the 'blind spot' within V1. The current results substantiate the assumption that neural activity in area V1 is closely related to our phenomenal experience of an illusory contour.

- ◆ **Pattern-selective cortical neurons show long-term stability in their stimulus preferences and temporal dynamics**
I V Bondar¶, D Leopold§, N K Logothetis (Max Planck Institute for Biological Cybernetics, Spemannstrasse 38, D 72076 Tübingen, Germany [¶ also Institute of Higher Nervous Activity and Neurophysiology, Russian Academy of Sciences, Butlerova 5a, 117485 Moscow, Russia]; §National Institutes of Health, Unit of Cognitive Neurophysiology and Imaging, 49 Convent Drive, Bethesda, MD 20892, USA; e-mail: bondar@ihna.ru)

Visually responsive neurons in the inferotemporal cortex of monkeys are known to modulate their activity in response to specific patterns, including complex shapes, objects, and faces. While neuronal selectivity in this region of the brain has been often examined, little is known about the maintenance of such selectivity over a period of days and weeks. Traditional recording techniques have provided only indirect information, and, given the suspected malleability of selective responses in these areas, it would be of great value to investigate the relative permanence of selective representations here. Recent advances in implantable electrodes have made it possible to record chronologically from isolated single units for periods of days and weeks. We tested monkeys on a simple fixation task, presenting a large number of complex patterns and images while monitoring action potentials with the implanted electrodes. We found that the stimuli elicited specific responses, and that the selectivity between neighbouring cells differed substantially. Furthermore, the diverse selectivity and temporal patterning characterising these neurons were generally maintained from session to session. The results suggest that individual neurons have remarkably specific and fixed roles in the analysis of complex stimuli over a period of days. [Supported by the Max Planck Society]

- ◆ **Classification image analysis of texture discrimination**
J D Victor, A Ashurova, M M Conte (Department of Neurology and Neuroscience, Weill Medical College of Cornell University, 1300 York Avenue, New York, NY 10021, USA; e-mail: jdvicto@med.cornell.edu)

Classification images (CIs) are a psychophysical probe of the computations underlying visual perception. However, application of CIs to texture discrimination is not straightforward, since standard reverse-correlation will not capture the contribution of second-order or higher-order image statistics. Five subjects identified the location of a 16×64 pixel texture-defined target within a 64×64 pixel background array. Target and background were chosen from a two-dimensional space of binary Markov random field textures, parameterised by their mean luminance and a 2×2 fourth-order correlation. Stimuli spanned the range of performance from near threshold to near ceiling.

4320 trials per subject were collected. CIs were determined after preprocessing stimuli to create 'derived images' representing pixel-by-pixel estimates of luminance or higher-order statistics. Reverse correlation yielded CIs that identified the footprint of the target but did not reveal internal structure. However, CIs extracted by regression combined with regularisation identified features not seen in the reverse correlation CIs: an accentuation of the contribution of luminance statistics, but not fourth-order statistics, near the target edge. Thus, CIs reflecting nonlinear processes may be readily obtained via analysis of appropriate derived images, and regularisation techniques may provide insights beyond those apparent from standard reverse-correlation maps. [Supported by NIH EY7977.]

◆ **Neuronal mechanisms of feature detection in cat V1**

I A Shevelev (Department of Sensory Physiology, Institute of Higher Nervous Activity and Neurophysiology, Butlerova 5a, 117485 Moscow, Russia; e-mail: shevelev2@mail.ru)

In experiments with narcotised and paralysed cats responses of striate neurons to light bars and cross-like figures were studied. Neurons of the primary visual cortex were found to be capable of positional and temporal, as well as selective or invariant encoding of the image features of the first and second order. About 50% of neurons gave a larger (by a factor of 3) response to a flashed cross, corner or Y-like figure centred in receptive field than to a single bar of preferred orientation. Most such neurons (72%) were highly selective both to the shape and orientation of figures, but we have also found neurons with an invariance of tuning to the orientation and/or shape of the figures. Cross-sensitivity was investigated also in striate neurons before, during, and after local blockade of intracortical inhibition by micro-iontophoretic application of bicuculline. Inhibition either produced or increased cross-sensitivity, or depressed it. The mechanisms and dynamics of tuning to crosses were studied: excitatory convergence and interaction between excitatory, end-inhibitory, and disinhibitory receptive field zones. The tangential package of the neuronal modules for feature processing studied by optical imaging is described. Possible functional implication of a second-order feature extraction in the striate cortex is discussed.

[Supported by the Russian Foundation for Basic Research (05-04-49649), Science School (NSh-2336.2003.4, MK-3026.2005.4).]

◆ **Dependence of latency on contrast in V1**

B J Richmond (Laboratory of Neuropsychology, NIMH/NIH, Building 49, Room 1B80, Bethesda, MD 20892, USA; e-mail: bjr@ln.nimh.nih.gov)

Recordings of supragranular complex cells in V1 of awake, fixating monkeys were taken while bars, gratings, and Walsh patterns were presented on the receptive fields. The responses of complex cells in the calcarine sulcus of V1 to unmoving stimuli flashed onto the receptive fields confirm previous studies of V1 neural activity showing a dissociation of response latency and response magnitude. Response magnitude carries accounts for most, if not all, of the available information about stimulus pattern, while latency accounts for most, if not all, of the available information about stimulus contrast. The mean latencies become longer at low firing rates, with the latencies appearing considerably longer for gratings than Walsh patterns or bars. However, the minimum latency is similar across all contrasts for a particular stimulus set. If spike trains are considered as stochastic samples from underlying rate profiles (approximated by peristimulus-time spike densities), the latency distributions across trials can be modeled quite accurately by order statistics, a branch of statistics that gives the distribution of ordered samples from underlying distributions. From these observations and this statistical model it is possible to characterise the dependence of latency on contrast, and its near independence from stimulus pattern.

[Supported by IRP/NIMH/NIH/DHHS, USA.]

◆ **A computational model of figure – ground organisation**

E Niebur, E Craft, H Schütze¶, R von der Heydt (Zanvyl Krieger Mind/Brain Institute and Department of Neuroscience, Johns Hopkins University, 3400 North Charles Street, Baltimore, MD 21218, USA; ¶ Otto von Guericke University, Leipziger Strasse 44, D 39120 Magdeburg, Germany; e-mail: niebur@jhu.edu)

Psychophysical studies suggest that figure – ground organisation is a largely autonomous process that guides—and thus precedes—allocation of attention and object recognition. The discovery of representation of border ownership in single neurons of early visual cortex has confirmed this view. Recent theoretical studies have demonstrated that border ownership assignment can be modeled as a process of self-organisation by lateral interactions within V2 cortex. However, the mechanism proposed relies on propagation of signals through horizontal fibres, which would result in increasing delays of the border ownership signal with increasing size of the visual stimulus, in contradiction to experimental findings. It also remains unclear how the resulting border ownership representation would interact with attention mechanisms to guide further processing. Here we present a model

of border ownership coding based on dedicated neural circuits for contour grouping that produce border ownership assignment and also provide handles for top-down mechanisms of selective attention. The results are consistent with neurophysiological and psychophysical findings. The model makes predictions about the hypothetical grouping circuits and the role of feedback between cortical areas.

BRAIN AREA INTERACTION

◆ Organisation of the primate brain in relation to visual and auditory activities

K Kawamura, F N Makarov¶ (Laboratory for Cell Culture Development, Brain Science Institute, Riken, 2-1 Hirosawa, Wako-shi, Saitama 351-0198, Japan; ¶ Laboratory of Neuromorphology, Pavlov Institute of Physiology, Russian Academy of Sciences, nab. Makarova 6, 199034 St Petersburg, Russia; e-mail: kokikawamura@brain.riken.jp)

Anatomical and physiological data of the higher function of the human brain are scanty. A lot more is known from experimental animals, so it is useful to discuss principles of morphology and function of the human brain in terms of findings in cats and monkeys. As the monkey visual cortex is subdivided into V1, V2, V3, V4, TEO, TE, MT, and MST, the auditory cortex is classified as the core (AI, R, and RT), the belt (CL, ML, and AL) and the parabelt (STGc, CPB, RPB, and STGr) regions. Visual and auditory impulses are known to converge in the cortical areas surrounding the middle suprasylvian sulcus (MSS) in the cat and the superior temporal sulcus (STS) in the monkey. The visual information proceeds to the prefrontal cortex via the parietal and temporal lobes. In the former, it is concerned with the information of the positioning in the space 'where', while in the latter, it is concerned with 'what' of the objects. Many fibres extend from the prefrontal cortex end in the temporal pole, where reciprocal connections are present with the amygdala and hippocampus, and further from there to the posterior STS region upon which polysensory inputs converge.

◆ A novel strategy for multiple-image working memory: Detect familiar among novel

V Yakovlev, D J Amit¶, S Hochstein§ (Department of Neurobiology [§ Life Sciences Institute and Interdisciplinary Center for Neural Computation], Hebrew University, IL 91904 Jerusalem, Israel; ¶ Dipartimento di Fisica, Università di Roma 'La Sapienza', piazzale Aldo Moro 2, I 00185 Rome, Italy; e-mail: volodya@vms.huji.ac.il)

Multiple-stimulus working memory was studied in a macaque monkey, trained to watch a sequence of (up to 6) stimuli and report repetition of one of the stimuli within the sequence. In experiment 1, a fixed set of 16 stimuli was used. Each sequence had a random length and a random choice of stimuli from this set. Thus, all stimuli were 'familiar' and good performance was achieved: 83% hits and only 3.2% false positives (FPs). In experiment 2, a set of 12 000 stimuli was used, and generally each stimulus was used only once. All stimuli were 'novel'—except for the final match stimulus on each trial. Surprisingly, performance was even better than with 'familiar' stimuli, reaching 91% hits and 2.6% FPs. In experiment 3 we retested performance with a new fixed set of 16 images and found that the experience with 'novel' images also improved performance with 'familiar' stimuli. We suggest that monkeys use a working memory for overtrained 'familiar' image sets, but depend on the change in visual response, due to familiarity, when tested with 'novel' images. The decay constant for the familiarity effect is estimated from the data.

[Supported by the National Institute for Psychobiology in Israel and a Center of Excellence grant from the Israel Science Foundation.]

◆ Organisation of clustered visual interareal cortico – cortical connections

F N Makarov, L A Markova, K Kawamura¶ (Laboratory of Neuromorphology, Pavlov Institute of Physiology, Russian Academy of Sciences, nab. Makarova 6, 199034 St Petersburg, Russia; ¶ Laboratory for Cell Culture Development, Brain Science Institute, RIKEN, 2-1 Hirosawa, Wako-shi, Saitama 351-0198, Japan; e-mail: fnm@infran.ru)

To study the pattern of distribution of clusters of initial neurons in the cat visual cortex, a technique of the axonal HRP transport and reconstructive morphometric methods were used in brain serial sections. The size of marker injection spots in area 21 was about 1.5 mm × 1.5 mm. Retrogradely labeled cells (1000–1300 in each case) were grouped in the form of round or ellipsoid clusters and were distributed over the lateral cortical surface of areas 17 and 18 and the medial surface of area 17. Intercluster distances were 700–800 µm in area 17, and twice longer in area 18. The orientation of long axes of clusters distributed along the 17/18 border was strictly perpendicular to it, whereas on the medial surface, its rostro-caudal orientation was less obvious. Comparative aspects of such neuronal clusters, which are peculiar to long forward connections from areas 17 and 18 to hierarchically high-level visual fields (areas 19, 21, and cortical zones in the suprasylvian gyrus) are discussed. These data can be useful for a more detailed morphological analysis of the complex cluster construction of intrinsic visual connections, which is caused by anisotropy of retinotopic magnification.

◆ **Neural circuits for executive control of sensitivity and bias in vision**

J Lauwereyns (School of Psychology, Victoria University of Wellington, PO Box 600, Wellington 6006, New Zealand; e-mail: jan.lauwereyns@vuw.ac.nz)

A theory of neural control is presented that accounts for the relationship between endogenous factors (goals, beliefs, expectations) and behavioural performance in visual tasks. Executive control of visual processing is implemented through two parallel systems, one synergistic system, dominated by a loop between prefrontal cortex and posterior association areas, and one prospective system, dominated by a loop between prefrontal cortex and the basal ganglia. The synergistic system modulates the gain of sensory input, leading to a multiplicative scaling effect on the tuning curve of individual neurons. Executive control can heighten sensitivity for stimuli associated with task relevance or reward. The prospective system generates an anticipatory bias that has an additive scaling effect on the tuning curve of individual neurons. Such a bias influences the a priori likelihood of detecting a stimulus, regardless of incoming sensory information. Executive control may create a bias for stimuli associated with task relevance or reward. Both systems send output to brainstem structures to increase the strength of specific action representations as a function of endogenous demand. Whether an action will be performed depends on the strength of its brainstem representation relative to representations of opponent actions and the drive to withhold any action.

[Supported by New Zealand Neurological Foundation; Marsden Fund Royal Society of New Zealand.]

◆ **Finding the link between 'what' and 'when': Recall of temporal order of a series of visual stimuli by macaque monkeys**

T Orlov, D J Amit[¶], V Yakovlev, E Zohary, S Hochstein (Department of Neurobiology, Life Sciences Institute and Neural Computation Center, Hebrew University, IL 91904 Jerusalem, Israel; [¶] Racah Institute of Physics, Hebrew University, IL 91904 Jerusalem, Israel, and Dipartimento di Fisica, Università di Roma 'La Sapienza', piazzale Aldo Moro 2, I 00185 Rome, Italy; e-mail: tanya@lobster.ls.huji.ac.il)

Every day we face the problem of having to store and retrieve sequences of visual events in the correct order. What mechanism underlies serial order ('when') memory? We recently found that macaque monkeys use a combination of mnemonic strategies when they recall the identity and order of short lists of images. Surprisingly, the dominant mnemonic routine for order recall involved long-term memory of temporal order categories, rather than item-to-item chaining or working memory of the sample images seen just before the recall task. We now show that these ordinal category labels are absolute, numerical categories (1st, 2nd, 3rd, ...), not relative (initial, intermediate, last). They are not based on fixed reward-contingency or image-familiarity ranking. We propose and test a novel dynamic image salience hypothesis for serial recall, based on top-down (category-to-image) influence and a salience computation for identifying targets. According to this hypothesis, category label populations serve sequentially as top-down pointers, temporarily increasing salience of images belonging to their category, leading to choice of appropriate images. The proposed flexible and dynamic mechanism integrates memories of a variety of origins (item and ordinal category memory, ordinal number categorisation, item-item associations, etc), via a single salience computation, to allow unitary behaviour.

[Supported by 'Center of Excellence' grants from the Israel Science Foundation and INFM, Roma-I, and a grant from the National Institute for Psychobiology in Israel.]

◆ **Human multi-channel ERP correlates of comparing visual information with sensory memory**

J D Kropotov (Institute of the Human Brain, Russian Academy of Sciences, Akad. Pavlova 9, 197376 St Petersburg, Russia; kropotov@ihb.spb.ru)

Comparison is a common operation in neuronal networks. In the sensory systems, the goal of this operation is to compare the incoming stimulus with the memory trace and to send the result of comparison further to the executive system. To study the comparison operations, a two-stimulus go/no-go task was designed. In the go/no-go task three categories of visual stimuli: 'animals' (a), 'plants' (p), and 'humans' (h) were presented in pairs: aa (probability of occurrence 25%), ap (25%), pp (25%), and ph (25%). The subject's task was to press a button in response to the aa pair. Comparison operation was assessed by analysing difference ERP waves and independent component analysis. 19-channel EEG was recorded in 250 subjects. A positive component with a peak latency of 240 ms and the maximum located at T5, T6 was found. The component appeared when the incoming stimulus did not match the prepared sensory model after presentation of the first stimulus as well as the second stimulus. This temporal positivity was accompanied by a negative component generated in the frontal areas in the no-go task condition (aa). Intracranial counterparts of the scalp-recorded ERPs were found. A neuronal model which explains the results of the experiments is suggested.

◆ **The principle of least action and visual perception**

Y E Shelepin, N N Krasilnikov, G A Trufanov, A K Harauzov, S V Pronin, V A Fokin (Pavlov Institute of Physiology, Russian Academy of Sciences, nab. Makarova 6, 199034 St Petersburg, Russia; e-mail: yshelepin@yandex.ru)

The mechanisms of brain area interaction were studied on the basis of the fundamental physical principle of least action. An experimental paradigm was used where subjects were required to discriminate scrambled and ordered images—matrices of Gabor patches of the same orientation (ordered) and with different orientations (scrambled). They are convenient for manipulating the geometry, but keeping the physical parameters (size, contrast) constant, which is necessary for physical methods of brain mapping (EEG, ERP, fMRI). Activation of the brain was achieved by rotation of matrix elements. The timing was measured and the spatial distribution of activity was reconstructed in the different brain areas during stimulus discrimination. Different brain area activities were established together with their interaction at each temporal stage of matched filtration processing. According to the theory of matched filtration, recognition in the visual system is carried out by finding the minimal differences between the actual image description and the description stored in the human memory as a template. The results permit us not only to use the Bayesian approach to discrimination paradigm models of images composed of ordered vs scrambled elements, but also support the importance of the least-action law in discrimination processes.

[Supported by RSSF grant 05-06-06085, RFFR grant 05-04-49032, and a Russian Academy of Sciences grant.]

◆ **Acquiring information from virtual environments: Perceptual and spatial issues**

N P Foreman (Department of Psychology, Middlesex University, Enfield Campus, Queensway, Enfield, London EN3 4SF, UK; e-mail: n.foreman@mdx.ac.uk)

Virtual environments (VEs) have been used in a variety of forms (desktop, immersion, wide screen projection) to allow training and visualisation while a participant is immersed in a virtual world. Clearly, there are many perceptual-cognitive differences between virtual images and interactivity compared with real-world equivalent experiences. However, VEs have proved useful for many practical applications. Spatial research has especially benefited, since spatial information acquired from virtual experience (even when provided on desktop monitors) is comparable to that obtained from real equivalent experience. Where disorientation has been reported in VEs, this may be due to distance underestimation effects. Studies are reviewed in which children, adults, and older adults have been trained and assessed in VEs in wayfinding and survey tasks. The special perceptual considerations that apply to VE use by older participants are discussed. The future of VEs in spatial training and assessment is evaluated.

VARIETIES OF MULTIPLE-OBJECT TRACKING

◆ **Expertise effect in enumeration: Subitising or counting?**

R Allen, P McGeorge (School of Psychology, University of Aberdeen, William Guild Building, Aberdeen AB24 2UB, Scotland, UK; e-mail: roy.allen@abdn.ac.uk)

Visual index theory suggests that a limited number of preattentive 'tags', which point to the locations of objects in the visual field, underpin multiple-object tracking (MOT) and subitising (the immediate apprehension of small number quantities without counting). Previously we have shown an expertise effect in an MOT task. However, our findings suggests that such expertise stems not from experts' greater number of preattentional tags but, instead, may be due to differing attentional strategies. Here, we report two recent experiments that tested novices and prospective experts (candidates preselected for radar operator training), both before and after training, on an enumeration (subitising/counting) task together with a concurrent auditory task. Such secondary tasks have previously been shown to impact negatively upon MOT performance. Results from experiment 1 show that prospective experts and novices differ significantly in their counting, but not subitising, performance. In experiment 2, the prospective experts' performance before and after basic training was compared. Results suggest that training resulted in an improvement to their counting ability. These findings are discussed in relation to the contribution attention makes to enumeration.

◆ **Dynamic binding of identity and location information for multiple moving objects**

L Oksama, J Hyönä (Department of Behavioral Sciences, National Defence College, PO Box 5, FI 04401 Järvenpää, Finland; ¶ Department of Psychology, University of Turku, FI 20014 Turku, Finland; e-mail: lauri.oksama@mil.fi)

A model is proposed to describe mechanisms responsible for tracking and maintaining multiple moving objects with distinct identities. The basic tenets of this MOMIT model are: (i) identity-location bindings are temporarily stored in an episodic buffer; (ii) bindings are refreshed by

serially attending to each target, one at a time; (iii) object familiarity affects the time needed to refresh bindings; (iv) focal attention is shifted between moving targets with the help of indexed location information stored in the visuospatial short-term memory and with the help of peripheral visual information; and (v) a location error is involved in the stored location information. We provide empirical evidence in support of the model: linear effects in performance accuracy of set size and object speed, an effect of object familiarity, and an interaction between set size and familiarity and between set size and speed. Moreover, the accuracy data were successfully simulated with a mathematical formulation of MOMIT.

◆ **What is tracked with dynamic multiple objects?**

J Saiki (Graduate School of Human and Environmental Studies, Kyoto University; Yoshida-Nihonmatsucho, Sakyo-ku, Kyoto 606-8501, Japan; e-mail: saiki@cv.jinkan.kyoto-u.ac.jp)

To understand what is tracked when we monitor multiple moving objects, we devised a paradigm called multiple object permanence tracking (MOPT), and investigated memory for feature binding by requiring observers to identify a violation in feature combination of multiple objects occurring during an occlusion. A series of behavioural experiments showed that, unlike a standard MOT, estimated capacity to hold feature binding of objects is quite limited. Object motion dramatically disrupts performance even when objects are easily trackable. Even when objects are stationary, we cannot identify the type of change, though simple change detection is possible. A 100% valid cue indicating a changing object just after the change helps performance only in change-detection task when objects are stationary. These findings suggest that we can hold salience representations when multiple objects are stationary, but these salience representations become unavailable when the objects are moving and occluded. Event-related fMRI experiments using MOPT tasks revealed significant activation of dorsal and ventral prefrontal cortex both in maintenance of feature binding and in change detection with dynamically moving objects. Taken together, what is tracked in a standard MOT may be simple spatiotemporal indices, and active involvement of prefrontal cortex is necessary to track object representations.

[Supported by 21st Century COE (D-2 to Kyoto University), and PRESTO from JST]

◆ **A sensory memory account for loss of positional information when tracking multiple trajectories**

S Narasimhan, S P Tripathy, B T Barrett (Department of Optometry, University of Bradford, Richmond Road, Bradford, West Yorkshire BD7 1DP, UK;

e-mail: S.Narasimhan@bradford.ac.uk)

To understand the nature of visual memory involved while tracking multiple objects, we performed several experiments using variations of the threshold paradigm of Tripathy and Barret (2004 *Journal of Vision* 4 1040–1043). Thresholds were determined for identifying a deviation in a single, bilinear target trajectory among multiple, linear distractor trajectories. When the distractors disappeared halfway through the trial, thresholds were high, suggesting that the traces of the first half of the target trajectory in memory might have decayed substantially prior to processing of the deviation. Introducing a temporal delay between the first and second halves of the trajectories elevated deviation thresholds substantially, presumably because of the increased additional decay of the traces in memory. Other experiments show that the number of trajectories that can be tracked at a time depends on the difficulty of the task involved, presumably because each trajectory now requires more processing time. But with static presentations, 'deviation' thresholds were low even with 10 simultaneously presented 'trajectories', since processing can begin before any decay of the traces. We propose an explanation based on the persistence of trajectory traces in visual sensory memory for these findings and suggest that this holds for much of the published literature on tracking multiple objects.

◆ **Tracking multiple objects in amblyopic vision**

S P Tripathy, D M Levi¶ (Department of Optometry, University of Bradford, Richmond Road, Bradford BD7 1DP, UK; ¶ School of Optometry, University of California, Berkeley, CA 94720-2020, USA; e-mail: s.p.tripathy@bradford.ac.uk)

Human observers can typically track about four moving items simultaneously (Pylyshyn and Storm, 1988 *Spatial Vision* 3 179–197), but when detecting near-threshold deviations in trajectories they can effectively track only one trajectory (Tripathy and Barrett, 2004 *Journal of Vision* 4 1020–1043). This 'effective' number of tracked trajectories ranges from one for a $\pm 19^\circ$ deviation to four for a $\pm 76^\circ$ deviation. In amblyopic vision, positional information and object enumeration are compromised (Sharma and Levi, 2000 *Nature Neuroscience* 3 496–501). Is the ability to track multiple moving objects compromised as well? We tested tracking ability in the amblyopic and fellow eyes of amblyopes using multiple moving stimuli. We used the paradigm of Tripathy and Barrett (2004, loco cit.) with observers detecting deviations in unknown target trajectories among linear distractor

trajectories. Near-threshold deviations and substantially suprathreshold deviations were tested. For detecting near-threshold trajectory deviations, both amblyopic and fellow-eye deviation thresholds were similar to those in normal observers. Similarly, for suprathreshold trajectory deviations, the effective numbers of trajectories tracked in both eyes of amblyopes were comparable to those of normal observers. We believe that the primary factor limiting tracking performance in normal observers is the persistence of visual sensory memory. The current findings suggest that this persistence is normal in amblyopes.

[DL was supported by grant RO1EY01728 from the National Eye Institute, NIH.]

TEMPORAL DYNAMICS

◆ The blue arcs of Purkinje

A Sobolev, J D Mollon (Department of Experimental Psychology, University of Cambridge, Downing Street, Cambridge CB2 3EB, UK; e-mail: aas31@cam.ac.uk)

The blue arcs, discovered by Purkinje in 1825, exhibit a topography that mirrors the well-established distribution of arcuate nerve fibres passing from nasal and temporal macular ganglion cell bodies to the optic nerve. One traditional hypothesis is that electrical activity in the arcuate bundle excites nearby cell bodies giving rise to two bright blue arcs. The aim of the current work is to study the time constants of the generation and the decay of the phenomenon. Possibly for the first time, a performance measure was used to examine the blue arcs: in a spatial 2AFC task, subjects were required to detect a small blue probe presented in the path of the arc. Eye position was concurrently monitored by a Cambridge Research Systems eye tracker. We have successfully measured a delayed 'on-effect', which reaches its maximum at 400 ms after the onset of the inducing stimuli, as well as an 'off-effect' that becomes apparent for stimuli over 900 ms. We have also recorded the rate of decay of the arcs at various durations of the inducer. The results suggest that between the onset of the inducer and the generation of the blue arcs there is an integration stage with a long time constant.

[Supported by Merck Sharp & Dohme and the James Baird Fund.]

◆ No benefit for synchronising complementary cues

S Louw, J B J Smeets, E Brenner (Faculty of Human Movement Sciences, Vrije Universiteit, Van der Boechorststraat 9, NL 1081 BT Amsterdam, The Netherlands; e-mail: S.Louw@fbw.vu.nl)

People are known to be quite bad at judging the synchrony of events. For instance, when asked to synchronise a change in colour with a change in direction of motion, or a sound with a tone, they often make errors of tens of milliseconds. We wondered whether people would be more accurate with cues providing complementary information about a single attribute. We studied combinations of two cues for motion in depth: changing retinal image size and changing binocular disparity. The two cues provide complementary information for judgments of motion in depth, while judgments of size rely on a combination of retinal image size and binocularly judged distance. Each cue changed in accordance with sinusoidal motion of a rigid object in depth. Subjects had to adjust the phase difference between the cues in order to either maximise the amplitude of a simulated motion in depth of the disk, or to maximise the change in its size; corresponding with setting phase differences of 0° and 180°, respectively. In both cases subjects made systematic errors of tens of milliseconds, and twice as large variable errors. The errors were not systematically smaller when both cues were interpreted in terms of motion of a rigid object.

◆ Temporal order judgments are modality specific: A perceptual learning study

D Alais, J Cass (Department of Physiology and Institute for Biomedical Research, School of Medical Science, University of Sydney, NSW 2006, Australia; e-mail: alaisd@physiol.usyd.edu.au)

We investigated whether time perception is central and supramodal or peripheral and modality specific. Subjects trained on temporal order judgments (TOJs) over 10 sessions (sufficient for asymptotic learning). Three groups were trained: visual, auditory, and bimodal. All groups began with pretests to measure TOJ thresholds on various stimuli: visual gratings (0° and 90° orientations), visual position, auditory tones (1 and 4 kHz frequencies), and bimodal (tone/grating) stimuli. Onset and offset TOJs were measured. After training on a task (vision: onset of two gratings; audition: onset of two tones; bimodal: onset of tone/grating pair) we re-measured TOJ thresholds for the same battery of conditions to see if improved TOJs were specific to the trained stimulus, or would generalise (eg across a feature dimension, or between modalities). In all groups, learning generalised across feature dimensions (ie TOJs improved for unlearned orientations, frequencies, and tone/grating pairs) but not from onset to offset (and not across visual location), and not between modalities. Neither did unimodal learning generalise to bimodal

conditions (nor vice versa). We conclude that lack of intermodal generalisation indicates separate timing mechanisms underlie unimodal TOJs (vision and audition), and that bimodal timing is a separate system. Lack of generalisation from onset to offset suggests separate mechanisms mediate these temporal events.

◆ **How to detect that something we do not remember has changed?**

H L Gauchou, J R Vidal¶, C Tallon-Baudry¶, J K O'Regan (Laboratoire de Psychologie Expérimentale, CNRS UMR 8581, Université Paris 5, 71 avenue Edouard Vaillant, F 92774 Boulogne-Billancourt, France; ¶ Laboratoire de Neurosciences Cognitives et Imagerie Cérébrale, LENA – CNRS UPR 640, Hôpital de la Salpêtrière, 47 blvd de l'Hôpital, F 75651 Paris, France; e-mail: helene.gauchou@univ-paris5.fr)

One frequently localises a change in a visual scene, without being able to report its nature. Moreover, in the 'visual sensing without seeing' effect described by Rensink (2004 *Psychological Science* 15 27–32) subjects know that something has changed but cannot report 'what' or 'how'. We present experimental data of five change-detection experiments that support a new model of change/no-change detection, 'the structural gist model', based on the use of two different aspects of the same information stored in visual short-term memory (VSTM): the individual and the relational information. The relational information exists within each feature dimension in VSTM, links information from individual units and needs no attention for its establishment. We suggest that, when a change occurs to an object that has no corresponding information in VSTM, the change could be detected, without being identified, because of the use of the relational information. The change-detection mechanism based on relational information could explain the change detection without identification phenomenon in general.

◆ **Attentional modulation by trial history**

J Schultz, H H Bühlhoff (Cognitive and Computational Psychophysics, Max Planck Institute for Biological Cybernetics, Spemannstrasse 38, D 72076 Tübingen, Germany; e-mail: johannes.schultz@tuebingen.mpg.de)

The temporal order of stimuli can affect performance and be critical for perceptual learning. We tested whether trial history can explain target detection time even when target occurrence is unpredictable. Twelve volunteers were presented with streams of stimuli of variable colour, shape, and motion direction, and had to attend to all stimulus dimensions simultaneously to report Poisson-determined, 1-back repetitions in any dimension. Response times decreased exponentially with the number of successive targets (group means for 1 to 4 targets in succession: 1050, 763, 717, 722 ms; 2-way repeated measures ANOVA: $F_{3,33} = 195$, $p \leq 0.0001$, no main effect of stimulus dimension but interaction between dimension and number of successive targets: $F_{6,66} = 5.11$, $p < 0.001$). Response times were well explained by a leaky integrator of trial history with a fast exponential decay [half-life = 1.21 trials; correlation coefficients significant at $p < 0.0002$ for all dimensions and subjects; group mean correlation coefficients for colour, shape and motion targets: 0.57 (0.03), 0.57 (0.02), 0.47 (0.03)]. Our results show that target detection times can be altered by trial history, and are explainable by a fast-decaying integration of trial history. We propose that trial history modulates attention, resulting in response time changes; we are currently investigating this hypothesis using functional neuroimaging. [Supported by the Max Planck Society.]

◆ **Comparing processing speed for complex natural scenes and simple visual forms**

S J Thorpe, S Crouzet, H Kirchner (Centre de Recherche Cerveau et Cognition UMR 5549, CNRS – Université Paul Sabatier Toulouse 3, Faculté de Médecine de Rangueil, F 31062 Toulouse Cedex 9, France; e-mail: simon.thorpe@cercu.ups-tlse.fr)

We recently showed that, when two complex natural scenes are flashed left and right of fixation, subjects can make reliable saccades to the side with an animal in as little as 120–130 ms (Kirchner and Thorpe, 2006 *Vision Research* 46 1762–1776). Here we used a much wider range of target images and a protocol where target category can shift from block to block, while keeping the pool of stimuli constant. Subjects were perfectly able to shift between categories such as 'animals' and 'means of transport', while maintaining high accuracy ($\approx 90\%$) and speed (mean RT ≈ 185 ms). This rules out explanations based on a natural bias of the oculomotor system towards certain types of stimuli. Even more surprisingly, we found that when much simpler visual features were used as targets (for example, saccade to the side with a vertical grating), neither accuracy nor speed was any better than for the complex visual scenes. In many cases, subjects were actually worse with the simpler stimuli. The results reinforce the view that processing in the visual system is optimised for meaningful and important stimuli with which the subjects have a lot of experience.

[Supported by CNRS, ANR Neuroscience, and EU project "Decisions in Motion".]

POSTER SESSION

VISUAL FUNCTION: TESTING AND TREATMENT

◆ **Light scattering effect on central and peripheral visual acuity**

G Ikaunieks, M Ozolinsh (Department of Optometry and Vision Science, University of Latvia, Kengaraga 8, LV 1063 Riga, Latvia; e-mail: Gatisik@lu.lv)

To assess the effect of light scattering on central and peripheral visual functions the visual-acuity thresholds were measured at the fovea and at different retinal eccentricities (0.5–4 deg) inducing different levels of light scattering. Black Landolt C optotypes with different colour backgrounds (grey, red, green, and blue) were used as stimuli. The luminance contrast for all stimuli presented on computer screen was the same (60%). Stimuli were viewed with the use of the best refraction correction. In order to generate different levels of light scattering, the electrically controllable polymer-dispersed liquid-crystal (PDLC) eye occluders were applied. For black stimuli on grey background the visual acuity thresholds were significantly different for two cases with and without light-scattering occluders only within 2 deg of the central fovea. Similar data for word acuity thresholds have been reported previously (Abdelnour and Kalloniatis, 2001 *Optometry and Vision Science* **78** 914–919) where contrast changes were applied directly to stimuli presented on computer screen. Results are compared with results of stimuli on red, green, and blue backgrounds. Main factors which cause reduction of visual acuity with PDLC eye occluders for coloured and achromatic stimuli are discussed. [GI is supported by the European Social Fund.]

◆ **Subjective measurements of visual acuity using vanishing figures**

S A Koskin, E V Boiko, A F Sobolev, Y E Shelepin¶ (Department of Ophthalmology, Military Medical Academy, Lebedeva 6, 194044 St Petersburg, Russia; ¶ Pavlov Institute of Physiology, Russian Academy of Sciences, nab. Makarova 6, 199034 St Petersburg, Russia; e-mail: koskin@mailbox.alkor.ru)

The aim of this study was the determination of visual acuity by using vanishing optotypes of different types. Acuity test Landolt Cs with a complex contour imitating various kinds of high-pass spatial-frequency filtering, generated as a printed visual-acuity charts with a grey background, were studied with regard to recognition thresholds. Comparisons were made between recognition thresholds of optotypes with a different complex contour. When the vanishing optotypes are out of focus, their image on the retina fades rapidly into the grey background, rendering them invisible rather than merely blurred as in a standard chart. Results confirm that the recognition distance depends on the physical property with a complex contour profile and show the importance of the Landolt C spatial-frequency spectrum for the recognition of different types of complex contours. The study shows that we can use vanishing-optotype charts with a different complex contour of stimulus as a control method for the determination of visual acuity or for detection of malingering.

◆ **Internal noise in the visual system and traditional clinical symptoms**

I Rudoy, A Deshkovich, Y E Shelepin, A K Harauzov, N N Krasilnikov¶, V A Fokin (Military Medical Academy, Lebedeva 6, 194044 St Petersburg, Russia; ¶ State University of Aerospace Instrumentation, Bolshaya Morskaya 67, 190000 St Petersburg, Russia; e-mail: yshelepin@yandex.ru)

We investigated the limits of vision by electrophysiological and psychophysical methods. We measured contrast sensitivity to gratings, chessboard patterns, letters, dots, and Landolt C in noise, by traditional optometry and vision-physiology tests. Additive and multiplicative external noise helps us to investigate different mechanisms of the visual acuity limitation of the fovea. We established the level of the internal noise contrast in the fovea. We measured signal/noise ratio for different stimuli at the fovea. We measured the contrast of internal noise in the fovea. The sampling noise is crucial in the fovea at the limit of resolution. Binocular vision optimises signal/noise ratio for sampling noise in the fovea. A good correlation of visual acuity measurement by the electrophysiological and the psychophysical method was obtained. We measured internal noise by fMRI. We compared the internal noise paradigm with the traditional clinical observation of optical hallucinosis.

[Supported by RHSF 05-06-06085; Russian Academy of Sciences basic research for medicine.]

◆ **Impaired perception of moving high-contrast and low-contrast optotypes by bradyopsia patients lacking RGS9**

A C Kooijman, F W Cornelissen, T P Dryja¶, J W R Pott§ (Laboratory of Experimental Ophthalmology [§ Department of Ophthalmology], University Medical Center Groningen, University of Groningen, PO Box 30 001, NL 9700 RB, The Netherlands; ¶ Department of Ophthalmology, Harvard Medical School, Massachusetts Eye and Ear Infirmary, 243 Charles Street, Boston, MA 02114, USA; e-mail: a.kooijman@ohk.umcg.nl)

Subjects with the recently defined disease bradyopsia have a phototransduction defect caused by an inactive RGS9 gene (Nishiguchi et al, 2004 *Nature* **427** 75–78). This defect delays the recovery

from illumination. Bradyopsia patients require 30 s to recover ERG amplitudes after a bright flash (normal 2 s) (Kooijman et al, 1991 *Documenta Ophthalmologica* **78** 245–254). They describe difficulties in vision in regular daylight. We studied the influence of luminance, contrast, and velocity on the visual resolution in bradyopsia patients to better understand their vision. Four subjects with bradyopsia, RGS9-W299R homozygotes, and twenty-two control subjects participated. Visual acuity (VA) versus luminance ($1-1200 \text{ cd m}^{-2}$) was assessed with high contrast optotype charts. Dynamic VA (DVA) versus velocity ($0-25 \text{ deg s}^{-1}$) was assessed with a single optotype presented on a computer monitor. We used four Weber contrasts at three background luminance levels ($10-100 \text{ cd m}^{-2}$). Patients' VA increased with luminance up to 10 cd m^{-2} and decreased above it. In controls, VA increased monotonously. DVA decreased in patients, but increased in controls with luminance. Patients' negative-high-contrast DVA was lower than positive-high-contrast DVA, whereas controls showed equal DVAs. Patients' low-contrast DVAs decreased with increasing luminance; in controls low-contrast DVAs increased with luminance. Vision impairment in bradyopsia patients at 10 cd m^{-2} and above can be attributed to the delayed recovery from light. Likewise, the lower negative-high-contrast DVAs can be explained.

◆ Neuromodulating effects of phosphenelectrostimulation

T V Degtyarenko, I M Boychuk, N N Bushueva, A G Chaura, V S Drozhenko (Institute of Eye Diseases and Tissue Therapy, Frantsuzsky blvd 49/51, 65061 Odessa, Ukraine; e-mail: boychuk.iryana@ukr.net)

We studied the directional effect of the influence of the optimal mode of phosphenelectrostimulation (PhES) on the visual, neurological, endocrine, immunological, psychological, and emotional state in children with spherical myopia (fifty-five subjects aged 11–15 years). The main indices of the above-mentioned systems were recorded before and after the treatment course. Evaluation of visual acuity, the latencies and amplitudes of flash visual evoked potentials (VEPs) in occipital and frontal parts of the cortex, antigens of the HLA-system, humoral immunity and phagocyte activity of leukocytes, psycho-emotional factors by Spilberger, MMPI, Lusher tests were performed on all children. We applied a 10-day course of PhES with the frequency of 15 Hz during 10 min. Visual acuity with and without correction increased after the treatment course. Latencies of P1 (occipital area) and P1 and N1 (frontal eye area) decreased after the treatment depending on the degree of myopia. Scores at some psycho-emotional tests positively improved, other indices were not changed significantly. The modulating effects of optimal mode of PhES on bioelectrical activity of the brain are thus established not only in sensory cortex, but also in motor cortex. This result supports the decrease of visual motor reflex time after treatment by PhES.

◆ The oblique effect in migraine

M S Tibber, A J Shepherd (School of Psychology, Birkbeck College, University of London, Malet Street, London WC1E 7HX, UK; e-mail: m.tibber@psychology.bbk.ac.uk)

There has been recent interest in orientation discrimination in migraine. To date, however, performance has been tested at a single orientation only and group differences have either failed to emerge, or have been found to depend on the spatial frequency of the stimulus. Consequently, it is unclear whether elevated thresholds in migraine are due to precortical dysfunction, or abnormal patterns of orientation tuning at cortical loci. A reduced sensitivity to oblique stimuli (the oblique effect) is thought to reflect cortical processing, eg a population bias at V1 and/or narrower tuning of cells tuned to cardinal stimuli due to recurrent intracortical synaptic connections. Orientation discrimination thresholds were calculated by using explicitly-drawn Gabor patches at cardinal (0°) and oblique (45°) orientations. In parallel, participants made orientation judgments using non-explicit (virtual) lines defined by two widely spaced circles that could not stimulate V1 receptive fields. Twenty migraine and twenty matched control participants were tested. Relative to the control group, the migraine group exhibited orientation-specific sensitivity losses on explicit and virtual judgments: orientation discrimination thresholds were significantly elevated in migraine about the oblique axis only. These findings reflect abnormal function of the striate and extrastriate cortex in migraine.

[Supported by Action Medical Research, SEARCH, Migraine Action Association, University of London Central Research Funds, and Birkbeck Faculty of Science.]

◆ The properties of internal noise in the visual system of patients with multiple sclerosis

S Muravyova, A Deshkovich¶, V A Fokin¶, Y E Shelepin (Pavlov Institute of Physiology, Russian Academy of Sciences, nab. Makarova 6, St Petersburg, 199034, Russia; ¶ St Petersburg Military Medical Academy, Lebedeva 6, St Petersburg, Russia; e-mail: mlanka@freemail.ru)

We tested the hypothesis that anatomical changes in visual pathways of patients with multiple sclerosis (MS) observed by anatomical MRI do not correlate with subjective psychophysics results.

We provided visual evoked potential recordings (VEPs), and psychophysical and functional MRI measurements in patients with multiple sclerosis (3–5 years from first manifestation). We then compared these results with the results of anatomical MRI and with the data from the brain slices. We observed that anatomical MRI method did not always demonstrate changes in the visual ways in patients with multiple sclerosis, whereas psychophysical measurements showed visual loss. Analysis of the brain slices obtained after occasional depth of some patients revealed clear demyelination in the visual pathways. Recordings of pattern-reversal VEPs to checkerboard patterns, presented on a uniform background or on a noise background, demonstrated an increase of latencies of VEP components and allowed us to establish the level of internal noise in healthy subjects and in the patients. Contrast of internal noise in patients in early stages of MS may be twice as high as in normal subjects. The great changes obtained by VEP measurements and small changes in visual pathways measured with anatomical MRI were compared with the use of the sensitive method of functional MRI.

[Supported by RHSF 05-06-06085; RAS basic research for medicine.]

◆ **Superior low-wavelength contrast sensitivity in asthenopsics during voluntary efforts to accommodation**

H O Richter, I Knez¶ (Centre for Musculoskeletal Research [¶ Department of Technology and Built Environment], University of Gävle, S 80176 Gävle, Sweden; e-mail: hrr@hig.se)

The purpose of this work was to characterise short-(S)-wavelength-sensitive-cone mediated contrast sensitivity (CS) across twenty symptom-free subjects and eight asthenopsics, all with normal-unaided-or-corrected visual acuity with no sign of oculomotor dysfunction. Threshold contrast sensitivity was assessed by the von Békésy tracking method from a viewing distance of 2.4 m (0.40 D). Three counterbalanced tasks required central fixation of black-and-white square-wave gratings (1, 5, 10, 14, and 17 cycles deg^{-1}) presented through a low-pass (400–450 nm) tinted blue lens: through (i) a 0.0 D lens, (ii) a -1.50 D lens, (iii) a +1.50 D lens while attempting volitional accommodation to minimise blur. Baseline increases in eye-strain, which approached high levels at the end of the experiment, did not differentiate between the two groups of volunteers. Compared with symptom-free subjects, asthenopsics exhibited larger magnitudes CS performance in the intermediate spatial frequencies during experimental conditions requiring voluntary increases in accommodation. The residual filtered light may encompass reference wavelengths habitually used by the asthenopsics in retinal alignment as an adaptive strategy to spare accommodation from eye-strain. Alternatively, asthenopsics, owing to inherent retinal factors, may 'drive' their accommodative system harder than symptom-free subjects.

[Supported by the Swedish Council for Working Life and Social Research Grant 2005-0488 to HR.]

◆ **Sensory and mental brain function after electrical stimulation**

A N Shandurina (Scientific Medical Center, Shkolnaya 7, 197183 St Petersburg, Russia; e-mail: shand@mail.rcom.ru)

The aim of this study was to test safety and effectiveness of pulsed-electrical therapy for restoring patients sensory and memory brain functions after intracranial surgery. Six planar electrodes were arranged in a hexagonal grid. Brief voltage pulses up to 2 V and 8–10 Hz were applied to selected electrodes. Standard optometry methods and psychological tests were used. Postoperative patients with visual and auditory deficits were selected. EEG recording was carried out and the index of the alpha-rhythm was measured. More than two thousand patients were treated. Most of them showed improvement of contrast sensitivity in the middle spatial frequency range and some of them showed increased visual acuity. There was also an improvement in patients accuracy in the performance of the computerised version of the Gollin memory test. An increase in the index of the alpha-rhythm was observed. Patients seem to improve their mental and sensory functions as electrical stimulation synchronises their intercell interaction as shown by the index of the alpha-rhythm in EEG.

◆ **Imaging processing of form and motion coherence in Asperger syndrome**

S Tsermentseli, J M D O'Brien, J V Spencer (Centre for Cognition and Neuroimaging, Brunel University, Uxbridge UB8 3PH, UK; e-mail: stella.tsermentseli@brunel.ac.uk)

We examined the neural bases of form- and motion-coherence processing in Asperger disorder by conducting an event-related fMRI study. The stimuli consisted of Glass patterns comprising dot triplets separated by a rotational transformation in space or dots rotated over time. Fixed levels of stimulus coherence were used ranging from 0% to 100%. The Glass pattern was embedded in a field of random dots and a participant's task was to identify its location to either the left or right of the central fixation point. The regions of interest (ROIs) were based on those previously identified as responding differentially to coherent motion and coherent form (Braddick

et al, 2000 *Current Biology* **10** 731–734). The BOLD response in all four motion ROIs was not significantly different between the two groups. A nonlinear relationship was found between the change in BOLD signal and form coherence for Asperger in the intraparietal sulcus compared to a linear relationship for controls. Even though this finding supports that there is a difference in the way visuospatial information is being processed in Asperger, this cannot at this stage be attributed specifically to visual deficits over non-perceptual factors such as attention.

◆ **‘Sticky attention’ in autistic spectrum disorder—visual psychophysics and movement**

A D Wilson, M Plumb, J H G Williams¶, M A Mon-Williams (School of Psychology, University of Aberdeen, William Guild Building, Aberdeen AB24 2UB, Scotland, UK; ¶Department of Child Health, Royal Aberdeen Children’s Hospital, Westburn Road, Aberdeen AB25 2ZD, Scotland; e-mail: andrew.wilson@abdn.ac.uk)

We compared children with ($n = 19$, age range 6–16 years) and without ($n = 112$) autistic spectrum disorder in a series of visual psychophysical and movement tasks. The tasks provided objective performance measures that tested previous claims based on subjective observations regarding autism. We found that children with autism: (i) were indistinguishable from controls in their form and motion coherence thresholds; (ii) were indistinguishable in their ability to detect subtle changes in realistic dynamic face stimuli; (iii) were indistinguishable in an imitation task requiring tracking a simple rhythmic movement; (iv) showed idiosyncratic differences in a joint attention task. In the joint attention task, targets moved around four corners of a screen during a 90 s video. Three conditions were explored: (i) a technician’s head displayed in the middle of the screen (baseline); (ii) the head moved congruently with target position; (iii) the head moved incongruently. The movement execution of the autistic group was indistinguishable from the controls but there were differences in reaction time. The children with autism fell into one of three groups: (i) normal; (ii) slower RT with congruent head movement; (iii) slower RT with incongruent head movement. We suggest that ‘sticky attention’ in autism can reconcile our laboratory findings with clinical observations.

◆ **Selecarten and Phospholuten improve the retinal function in the experimental damage of rabbit retina**

I V Tsapenko, N E Shvetsova¶, A N Ivanov¶, R A Gundorova¶, M V Zueva (Laboratory of Clinical Physiology of Vision [¶ Department of Ocular Trauma and Reconstructive Surgery], Moscow Helmholtz Research Institute of Eye Diseases, St Sadovaya-Chernogryazskaya 14/19, 105064 Moscow, Russia; e-mail: sunvision@mail.ru)

Our purpose was to determine the protective influence of Selecarten (SeC) and Phospholuten (PhL), the nano-selenium-rich substances, on ERG dynamics after laser damage of rabbit retina. Laser damage of the retina was created in both eyes of nine chinchilla rabbits (20 fusional coagulates, 400 mW, 0.1 C, 100 μ m) as a model of retinal focus pathology. SeC and PhL as complexes of selenium, phospholipids, Kalidon extract, and (in the case of SeC only) beta-carotene were injected subconjunctivally, intravitreally, or by instillation in different dosages to the right eyes, whilst BSS was used for the left eyes. Single-flash and flicker ERGs were registered before and after the retinal damage and treatment. The follow-up period was 3 months. SeC and PhL improved the retinal functional activity in all the experiments. In the control eyes, a more severe reduction of ERGs was revealed. The ERG data matched the data of ophthalmoscopic examinations and OCT. The positive effect of treatment was dose-dependent. The most protective influence was determined for subconjunctival SeC. Thus we found that SeC and PhL improve retinal functional activity after laser damage of rabbit retina.

◆ **The phosphenelectropuncture as a new method of restoration of accommodation in patients with accommodative dysfunction**

I M Boychuk, O Y Terletskaia, V S Ponomarchuk, S B Slobodyanik (Filatov Institute of Eye Diseases and Tissue Therapy, Frantsuzsky blvd 49/51, 65061 Odessa, Ukraine; e-mail: iryna54@mail.ru)

We investigated the influence of a new method of phosphenelectropuncture (PHEP) on accommodation and visual acuity in patients with accommodative dysfunction. One hundred and eighteen patients, aged 6–17 years, with accommodative dysfunction were examined. For the treatment we proposed a new method—PHEP—which is based on the electrical stimulation of paraorbital biological active points by electrical impulse with the triple threshold power which induce the phosphene phenomenon in the eyes. The results of the treatment were estimated by the indexes of accommodation, visual acuity, and pupil area. After the treatment the accommodative indexes as well as the visual acuity were found to improve in 92% of patients. The accommodative indexes have more than doubled, rising from 1.49 ± 0.08 D to 4.36 ± 0.12 D. The pupil area decreased from

$17.16 \pm 0.22 \text{ mm}^2$ before treatment to $10.8 \pm 0.19 \text{ mm}^2$ after treatment. The results of the treatment depended on the type of the refraction. The assumed mechanisms of PHEP are connected with the structures of the autonomic nervous system. The new PHEP method is very effective in treatment of patients with accommodative dysfunction accompanied by low degrees of ametropies.

◆ **Computer simulations of spatial misperceptions in amblyopic vision**

A M Iftime[¶], C C Baeumer[¶], R Sireteanu (Department of Neurophysiology, Max Planck Institute for Brain Research, Deuschordenstrasse 46, 60528 Frankfurt am Main, Germany; [¶] also Department of Biological Psychology, Institute for Psychology, Johann Wolfgang Goethe University, Mertonstrasse 17, D 60054 Frankfurt, Germany; e-mail: iftime@mpih-frankfurt.mpg.de)

We investigated quantitatively the spatial and temporal visual misperceptions reported by strabismic and anisometropic amblyopes. Fourteen subjects with strabismic ($N = 7$), anisometropic ($N = 4$) and mixed amblyopia ($N = 3$) were asked to describe and sketch their subjective percept of different geometrical patterns, as seen with the amblyopic eye. Based on their descriptions, computer-animated patterns were generated, which were then validated by the subjects. In a second experiment, the subjects were asked to construct geometrical patterns monocularly point-by-point, using the amblyopic or the fellow eye. The results of the distortions predicted by this mapping experiment were compared with the computer-generated reconstructions of the subjective percepts of the same subjects. We found that both spatial distortions and temporal instability were perceived mainly by strabismic and strabismic–anisometropic amblyopes. Temporal instability occurred only at higher spatial frequencies. The distortions predicted by the mapping experiment were well correlated with the perceptual descriptions of the same subjects for lower, but not for higher spatial frequencies. Our data suggest that strabismus, in addition to amblyopia, is needed to elicit significant spatial and temporal distortions. The occurrence of these distortions might be related to the early history of each subject.

[Supported by grants from the Deutsche Forschungsgemeinschaft to Ruxandra Sireteanu (SI 344/17-1,2).

◆ **A general assessment of visual functions in hearing-impaired adults**

N A Krasnoperova, T Y Cherepennikova, G I Rozhkova (Moscow Pedagogical State University, Malaya Pirogovskaya 1, 119992 Moscow, Russia; e-mail: gir@iitp.ru)

So far, the data concerning enhancement or inferiority of visual capabilities in deaf subjects seem to be contradictory. Taking into consideration a wide variety of visual capabilities, it would be expected that different visual functions could be modified by auditory deprivation in different ways and to variable degrees. In our study, a general assessment of visual functions was performed in eighty hearing-impaired adults (19–24 years old) and in one hundred and fifteen control subjects of the same age but with normal hearing. Among others, the measures included refraction, phoria, visual field, monocular and binocular visual acuity, stereoacuity, visual performance, etc up to a total of 19 indexes. The groups did not show differences in refractive errors or visual acuity. The number of hearing-impaired subjects whose visual field was reduced in temporal direction exceeded the corresponding number of control subjects by 30%. The hearing-impaired subjects also showed a reduction in critical flicker frequency, stereovision, and visual performance. In contrast to other studies (eg Rettenbach et al, 1999 *Journal of Cognitive Neuroscience* 11 560–583), we have not found a compensation for deafness in our attention-dependent tasks, probably because our tasks involved more prolonged manipulations or because most of our subjects had residual hearing.

◆ **Congenital prosopagnosia: A family study**

L Schmalzl, R Palermo, M Coltheart (Macquarie Centre for Cognitive Science, Macquarie University, Sydney, NSW 2109, Australia; e-mail: lschmalzl@macqs.mq.edu.au)

Prosopagnosia refers to a selective difficulty in recognising familiar people by their faces. While it has mostly been documented as a consequence of brain damage due to stroke or traumatic brain injury in people who had normal face recognition prior to the occurrence of this damage, it can also be present from birth (congenital prosopagnosia). Face recognition in a young boy and girl, both with congenital prosopagnosia, was studied. The specific reasons for their impaired face recognition were investigated by using assessment tasks designed to target various of the processing steps involved in face perception, such as the detection of first-order relations that define faces (two eyes above a nose and a mouth), holistic processing (perceiving the face as a Gestalt), and the processing of second-order relations (the spacing amongst facial features). The fact that these two children were siblings suggested that their prosopagnosia might be genetic in origin. Hence the assessment tasks were administered to four generations of their family. Four further family members showed clear impairments of face recognition, being able to identify

less than 60% of familiar faces. The findings strongly suggest that the children's prosopagnosia was genetically based.

[The Macquarie Centre for Cognitive Science is funded by the Australian Research Council (ARC).]

◆ **Motion discrimination in acute mania: A decision-making study**

M Barekattain, M Sanayei¶§, S Nasr§ (Department of Psychiatry and Center for Neural Science, Isfahan University of Medical Sciences, Noor University Hospital, Ostandari Street, PO Box 81465-993, Isfahan, Iran; ¶ Neuroscience Research Group, Isfahan University of Medical Sciences, Isfahan, Iran; § School of Cognitive Sciences, Institute for Studies in Theoretical Physics and Mathematics (IPM), Niavaran, Tehran, Iran; e-mail: barekattain@med.mui.ac.ir)

Decision-making, as a complex and important function for daily life, is often impaired in manic episode of bipolar I disorder (BID). Decision-making can be assessed quantitatively with a simple two-choice task. In this study, we used motion discrimination task in order to establish subjects' ability for decision making. Nine adult DSM-IV-diagnosed BID patients with psychotic mania and eight normal comparison subjects (NC) were tested with a motion-discrimination task. In this task, subjects should discriminate leftward or rightward motion direction of dots in the presence of different levels of noise (0–100%). Motion was generated by presenting a random-dot pattern which moved on the screen with different levels of coherence. The level of coherence and the direction of motion were selected pseudorandomly in each trial while the performance and reaction time of the subjects were monitored. Speed and accuracy were stressed. BID patients showed significant impairment in both reaction time ($p < 0.001$) and performance ($p < 0.05$) compared to NC subjects at high levels of noise. In comparison, there were no differences between BID and NC in more coherent motions. Decision-making in manic patients appears to be impaired which is consistent with previous studies that imply disturbed frontal and parietal activities in this syndrome.

◆ **A new method of stereo-amblyopia treatment on the basis of a binocular retinal photostimulation with patterns of spatial-depth orientation**

V A Kolomiets, Y O Hernaha (Filatov Institute of Eye Diseases and Tissue Therapy, Frantsuzsky blvd 49/51, 65061 Odessa, Ukraine; e-mail: ket26@ukr.net)

We studied the influence of binocular retinal photostimulation of appropriate fields with patterns of spatial-depth orientation to restore binocular and depth vision in patients with refractive amblyopia (RA) and strabismic amblyopia (SA). The treatment effect is related to photostimulation of binocular neurons in the visual cortex by stereopatterns, and to improvement of metabolic processes and blood circulation in cortical centres. The method was applied to 62 patients (aged 4–17 years). Visual acuity, binocular vision and depth perception were examined. The photostimulation was performed at sinoptophor. The power of the polychromatic light pulse was 2 mJ cm^{-2} . The size of the stimulated patterns was 10 deg. Daily treatment consisted of five procedures at 5 min intervals. The course of treatment lasted 10 days. In RA group of patients, the number of subjects who had satisfactory depth vision was increased by 35.2% after treatment. The ability of depth perception was restored in 75% patients who had no depth vision. In SA group of patients, binocular vision was absent before the treatment, but after the treatment binocular vision was restored in 28%. In 50% of these patients, the ability of depth perception was also restored.

◆ **Training software in treatment of amblyopia**

E L Efimova, V M Kononov (Department of Ophthalmology, State Pediatric Medical Academy, Litovskaya 2, 194100 St Petersburg, Russia; e-mail: Kosta22@mail.wplus.net)

The purpose of our study was to assess the efficiency of computer trainings in treatment of amblyopia. We used interactive software that allowed us to generate visual stimuli of variable form, size, and colour and to present them in groups. The task of a patient was to find the object shown in the centre among a number of peripheral objects. During each training session (10–15 min), the patient had to perform up to 100 exercises. The patients were children aged 4–15 years with refractive, strabismic, and combined forms of amblyopia. In cases of weak amblyopia, regardless of its etiology, 8–10 training sessions were usually enough to reach the normative visual acuity level (1.0 decimal units). In children with refractive amblyopia of moderate and severe degrees, the improvement of visual acuity due to a course of 30 sessions reached 0.4–0.5 decimal units. In cases of combined refractive–strabismic amblyopia, such courses were less effective, resulting in an increase of visual acuity by 0.2–0.3 decimal units, depending on the severity of the disease. In some children with strabismus, improvement of visual acuity was followed by a decrease of squinting eye deviation and partial recovery of binocular functions.

◆ **Complex contextual suppression in schizophrenic patients**

M Roinishvili, E Chkonia¶, A Kezeli, M H Herzog§, A Brand# (Laboratory of Vision Physiology, I Beritashvili Institute of Physiology, Georgian Academy of Sciences, Gotua 14, 0160 Tbilisi, Georgia; ¶ Department of Psychiatry and Medical Psychology, Tbilisi State Medical University, Asatiani 10, 0177 Tbilisi, Georgia; § Laboratory of Psychophysics, Brain – Mind Institute, École Polytechnique Fédérale de Lausanne, CH 1015 Lausanne, Switzerland; # Center for Psychiatry and Psychotherapy, Clinicum Bremen-Ost, 40 Züricher-Strasse, D 28235 Bremen, Germany; e-mail: maya_ro2002@yahoo.com)

Several studies showed that schizophrenic patients have impaired visual contextual processing. Whereas contextual facilitation is often diminished, we found recently that contextual suppression is intact and powerful. Here, we show that the effect of suppressive contextual stimuli can be diminished by protective contextual elements. We presented a Vernier that was followed by a mask of four types: (i) a grating comprising 25 elements, or this grating with (ii) two long horizontal lines above and below, (iii) two vertical collinear lines above and below the middle grating element, or (iv) the long horizontal lines and the collinear lines combined. The observers' task was to discriminate the Vernier offset direction. There was no noticeable difference of performance between conditions (i) and (ii), whereas performance strongly deteriorated when the single collinear lines were presented with the grating (iii). When we added the two long horizontal lines between the grating and the collinear lines (iv), performance improved compared to condition (iii). Hence, adding the 'neutral' contextual lines counteracted against the contextual suppression exerted by the single collinear lines. Schizophrenic patients and healthy controls show the same pattern of change. Schizophrenic patients, however, need longer target processing times (SOA) than controls. [Supported by the Volkswagen Foundation.]

◆ **Defective top – down feedback to visual cortical areas in patients with neglect**

D Spinelli, F Di Russo, T Aprile, G Spitoni¶ (University Institute for Motor Sciences (IUSM), 15 piazza de Bosis 15, I 00194 Rome, Italy; also IRCCS Santa Lucia Foundation, via Ardeatina, Rome, Italy; ¶ IRCCS Santa Lucia Foundation, via Ardeatina, Rome, Italy; e-mail: donatella.spinelli@iusm.it)

Patients with spatial heminattention (neglect) following right brain damage fail to orient to, or report stimuli located in the left contralesional space. Primary sensory areas are often spared; the disorder is considered a high-order deficit, rather than a sensory – perceptual one. In the present study we evaluated the hypothesis of normal vs abnormal visual processing for stimuli on the contralesional side. VEPs were recorded in eleven patients with neglect, with a dense electrode array. V1, dorsal V3A, and ventral V4 were activated by left and right stimuli in a comparable way. Visual processing in the parietal areas was altered. Anterior N1 (130–160 ms) arising from intra-parietal sulcus in the dorsal parietal cortex was missing for left stimuli and reduced for right stimuli. A first-stage feedback on striate and extra-striate areas, represented by parietal–occipital N1 (140–180 ms), and a further stage of feedback, represented by parietal–occipital P2 (180–220 ms), were delayed and reduced in amplitude for stimuli in the contralesional space. Results are discussed in terms of the effect on stimulus awareness of an altered top–down feedback on visual areas.

◆ **What can we learn from prosopagnosia about face processing?**

C-C Carbon (Department of Psychological Basic Research, Faculty of Psychology, University of Vienna, Liebiggasse 5, A 1010 Vienna, Austria; e-mail: ccc@experimental-psychology.com)

Prosopagnosia (PA) is a disorder concerning the recognition of familiar faces. Research papers discriminate between an acquired (aPA) and a congenital form of prosopagnosia (cPA). Here, the focus was on research on cPA and, mainly, implications of results from cPA research for general theories of face processing. In experiment 1, a simultaneous matching task was used with faces and houses as stimuli. Both object classes varied by relational, featural, or local (colour) aspects. Only for faces, but not for houses, people with cPA were severely impaired in recognition of stimuli which varied by relational aspects. In experiment 2, participants had to detect thatcherised faces (Carbon and Leder, 2005 *Perception* **34** 1117–1134) in a speeded recognition task. For people with cPA, our data showed a strong linear relationship between the deviation of the presented faces from an upright orientation and RT. In contrast, the data of the controls revealed a sigmoid function of RT. This indicates that cPA is based on impairments of configural/holistic face processing. Thus, configural/holistic processing seems to be a key ability with respect to general face processing and what we call 'face expertise'

◆ **Are temporal and spatial characteristics of visual scan paths heritable?**

P E G Bestelmeyer, B W Tatler¶, L H Phillips, P Benson, D St Clair (School of Psychology, William Guild Building, University of Aberdeen, Aberdeen AB24 2UB, Scotland, UK;

¶Department of Psychology, University of Dundee, Dundee DD1 4HN, Scotland, UK; e-mail: p.bestelmeyer@abdn.ac.uk)

Visual scan paths, a pattern of foveal fixations and voluntary saccades produced when an individual views an image, have been proposed by Loughland et al (2004 *Schizophrenia Research* 67 11–21) to serve as a potential trait marker for schizophrenia. To serve as a marker for genetic vulnerability to psychosis, scan paths need to be heritable. In a study of fourteen monozygotic twin pairs (MZ), fourteen dizygotic twin pairs (DZ), and fourteen unrelated control pairs we investigated whether temporal aspects of scan paths (eg number of fixations, fixation duration, saccade duration, saccade peak velocity, and saccade amplitude) and spatial variables (the fixation distributions) are more similar in MZ twins than in DZ twins and controls. There was no difference between the MZ, DZ, and control groups in terms of temporal characteristics of scan paths. However, MZ twins showed more overlap in the spatial distribution of areas selected for fixation than pairs of DZ twins and unrelated controls. Therefore spatial but not temporal scan path variables may serve as a vulnerability marker for illnesses such as schizophrenia.

[PEGB was supported by a PhD studentship from the College of Life Sciences and Medicine, University of Aberdeen.]

◆ **Visual function dynamics at visual fatigue**

V V Kolbanov (Academy of Postgraduate Pedagogical Education, Lomonosova 11, 191002 St Petersburg, Russia; kolbanov@atlant.ru)

An investigation of visual work capacity was carried out on forty-three healthy men aged 19–42 years (car drivers, telegraphists, video-record operators, and watch fitters). Direct exponents of work capacity were controlled. Visual acuity, accommodation, critical fusion frequency (CFF), colour contrast sensitivity, and blind spot size were investigated. These investigations showed that, in those cases of fatigue when the visual function was most significant for the performance of professional duties, it changed very little and unreliably, but decreased significantly and reliably statistically when it was not essential for the work capacity. For example, functions of near visual field periphery, being of minor importance, did not maintain their constancy. The results revealed also the relative character of visual fatigue redistribution. At the subcompensation stage, the most loaded function preserves its initial level and even can improve for a certain period of time. At the decompensation stage, the leading function decreased. Thus, in order to estimate the functional state of the visual system we need information not only about main function exponents, but also of changes that take place within second-rate functions, reflecting the activity of functional reserves.

◆ **Scattering-induced luminance and colour contrast decrease in visual perception**

M Ozolinsh, M Colomb¶, J Parkkinen§, G Ikaunieks, S Fomins, V Karitans, G Krumina (University of Latvia, 8 Kengaraga Street, LV 1063 Riga, Latvia; ¶Laboratoire Régional des Ponts et Chaussées (LRPC) de Clermont-Ferrand, F 63014 Clermont-Ferrand, France; §Color Research Laboratory, University of Joensuu, FI 80101 Joensuu, Finland; e-mail: ozoma@latnet.lv)

The main impact of light scattering on vision tests is a deterioration of visual performance due to the decrease of luminance and colour contrasts of retinal images. We showed earlier that lowering of visual acuity and contrast sensitivity by scattering in the monochromatic case has the greatest effect on the perception of shorter-wavelength blue–black stimuli. For polychromatic stimuli, however, both luminance and colour contrast changes should be taken into account (Ozolinsh et al, 2006 *Visual Neuroscience* 23 591–601). Here, we present results of subsequent experiments on the perception of various polychromatic stimuli: high-contrast or isoluminant stimuli under different scattering conditions, such as natural fog; obstacles with various scattering degrees and spectral dependences; and digital simulation of scattering on presented stimuli. For the two latter cases, attenuation of the transmitted light was taken as a measure of the degree of scattering. Studies revealed that the extent of decrease of static and dynamic visual acuity and contrast sensitivity, and increase of the visual-search time due to scattering were greatest when distinguishing green stimuli on a white background, with no spatial modulation of the blue contribution over all areas of presentation of polychromatic stimuli.

◆ **The allocation of endogenous visual attention in Parkinson's disease**

M V Baldo, A M Mota, K C Silva (Department of Physiology and Biophysics, Institute of Biomedical Sciences, University of São Paulo, São Paulo, SP 05508-900, Brazil; e-mail: baldo@icb.usp.br)

Several studies have revealed cognitive deficits in Parkinson's disease (PD) patients, suggesting a role for dopamine in cognitive functions. These functions robustly include attentional processes, indicating the involvement of the dopaminergic system in attentional modulation. Here we describe our attempt to assess the performance of three groups of volunteers (PD patients and normal elderly and young subjects) under two complementary visual tasks: the measure of simple reaction times (RT) to a single target and the temporal order judgment (TOJ) of two asynchronous stimuli (presented in opposite hemifields). In both tasks, attention was cued to a previously chosen hemifield. In comparison with normal elderly and young volunteers, PD patients showed longer RTs, a larger shift in the point of subjective simultaneity and a steeper decay in temporal discriminability (as the inter-stimulus asynchrony was decreased in TOJ tasks). These findings may be interpreted as a declining ability of PD patients to direct, sustain, or rapidly reallocate the focus of visual attention. The marked impairment in the voluntary allocation of visual attention shown by these patients lends support to the putative role of the dopaminergic system in the neural mechanisms of attentional modulation.
[Supported by FAPESP and CAPES (Brazilian funding agencies).]

◆ **Biological motion and face perception in autistic spectrum disorder**

K Ruparelía, J M D O'Brien, J V Spencer, H C H Hill¶, A Johnston§ (Centre for Cognition and Neuroimaging, Brunel University, Uxbridge UB8 3PH, UK; ¶ Department of Vision Dynamics, Human Information Science Laboratories, ATRi, Keihanna Science City, 2-2-2 Hikaridai, Seika-cho, Soraku-gun, Kyoto 619-0288, Japan; § Department of Psychology, University College London, Gower Street, London WC1E 6BT, UK; e-mail: kavita.ruparelía@brunel.ac.uk)

Studies have shown that typically developing individuals are very sensitive to visual cues generated by humans and animals. The human visual system enables us to categorise sex and identity through recognition of biological motion of faces, and these abilities take place at less than 12 months of age. In autism, there is evidence of both face- and motion-processing deficits, yet we do not know the extent of any deficits in facial-motion processing. To investigate whether motion provides useful information for categorising faces we conducted a computer-animated study on a group of adults with autism and a matched control group. The categorisation process involved discriminating sequences of animations of an average head with movements captured from real people. These stimuli had identical spatial characteristics and differed only in the way they moved. They were shown upright, inverted, forwards, and backwards. We report that the autistic observers showed consistently higher discrimination thresholds in all conditions than the control group. This corresponds with previous findings of visual recognition of biological motion with point-light displays. This finding is discussed with respect to extracting sophisticated information for social interaction and communication from faces and biological motion in the autistic population.

◆ **Facial emotion recognition is affected in social phobia and panic disorder**

J P M de Sousa, J A S Crippa, A S Filho, M C S Freitas, F L Osório, C A Baptista, C Trzesniak, S R Loureiro, J E C Hallak (Department of Neurology, Psychiatry and Medical Psychology, University of São Paulo, Hospital das Clínicas da Faculdade de Medicina de Ribeirão Preto, Laboratório de Psicofarmacologia—3º andar, avenida Bandeirantes, s/n, Ribeirão Preto, SP Brazil; e-mail: jpmppaulos@yahoo.com.br)

Research evidence suggests that the perception of facial emotions may be impaired in different psychiatric disorders, possibly leading to social malfunctioning. Researchers investigated the patterns of facial emotion recognition in social phobia (SP) and panic disorder (PD), compared to controls. Volunteers were recruited from university campuses and divided according to diagnosis in three groups: SP (64), PD (28), and controls (46). The task was composed by stimuli extracted from the series 'Pictures of Facial Affect' by Ekman and Friesen, morphed into different emotional intensities ranging from 0% (neutral face) to 100% (full emotion), displaying six emotions: happiness, fear, sadness, surprise, anger, and disgust. Participants were asked to label facial emotions presented progressively in pictures with gradual increases of 10% in emotional intensity. Percentage of emotional intensity required for recognition, time, and accuracy were measured. PD patients made more mistakes compared to controls, and SP patients labeled emotions with the same accuracy as controls, though requiring less emotional intensity for judgment. Investigation is recommended of the anxiety mechanisms underlying both illnesses.

◆ The role of the amygdala in the recognition of fearful faces

F Gosselin, M L Spezio¶, P G Schyns§, R Adolphs¶ (Département de Psychologie, Université de Montréal, CP 6128, succursale Centre-Ville, Montréal, Québec H3C 3J7, Canada; ¶HSS, Caltech, Pasadena, CA 91125, USA; § Department of Psychology, University of Glasgow, 58 Hillhead Street, Glasgow G12 8QB, Scotland, UK; e-mail: frederic.gosselin@umontreal.ca)

Adolphs et al (2005 *Nature* **433** 68–72) have gathered compelling evidence suggesting that SM, a woman with a bilateral amygdala lesion, has trouble discriminating fearful from happy faces because her gaze is not spontaneously directed toward the eyes of faces. Here we report a series of tests of this hypothesis. First, we explicitly instructed SM to look at the eyes of 1024 fearful and neutral faces, each decomposed in the Steerable pyramid space and sparsely revealed by randomly located Gaussian holes, while she performed a facial expression discrimination task (for details see Gosselin and Schyns, 2001 *Vision Research* **41** 2261–2271; Adolphs et al, 2005, loco cit.). SM's performance was within the normal range. Linear regressions on the holes and accuracies revealed that SM used high-spatial-frequency eye information when explicitly instructed to do so. Next, we checked whether the drop in spatial acuity with eccentricity can account for SM's performance. We replayed as faithfully as possible what SM saw during the Adolphs et al (2005, loco cit.) basic facial expression recognition task to ten normal individuals and asked them to identify the displayed facial expressions. Their performance was not impaired. These new results suggest that the amygdala is involved in directing attention rather than gaze toward high spatial frequencies within the eye region.

◆ Fatigue in a motion-onset detection task

M Tamm¶, K Kreegipuu§, J Allik¶§ (¶ Department of Psychology [§ Estonian Centre of Behavioural and Health Sciences], University of Tartu, Tiigi 78, EE 50410 Tartu, Estonia; e-mail: maria277@ut.ee)

Effects of mental or physical fatigue on the detection of visual motion onset were assessed. Thirteen nonsmoking men (mean age 20.6 ± 2.7 years) participated in a simple reaction time (RT) to motion-onset experiment four times (before and after 45 min of mental or physical task inducing subjectively an equal amount of fatigue). The stimulus consisted of a field of 960 squares with a randomly chosen average luminance value of 30.123 cd m^{-2} . After a random foreperiod of 0.8–1.6 s the field started to move either to the right or to the left with a constant velocity of 0.16, 0.31, or 1.24 deg s^{-1} , and the observer had to indicate the detection of motion by a mouse click. RTs increased with mental fatigue. Mental fatigue also increased the variability of RTs (ie SD) so that SD for the mental post-test RT differed from the mental pre-test ($t = -2.71$, $df = 12$, $p = 0.02$, dependent t -test) and the physical post-test ($t = 2.61$, $df = 12$, $p = 0.02$, dependent t -test) SD. A platelet monoamine oxidase isoenzyme B (MAO-B) activity which has been shown to correlate negatively to sensation seeking, monotony avoidance, and impulsiveness, is demonstrated to be a marker of the performance and fatigue effects in the simple RT task.

Supported by ETF 6244.]

VISION THROUGH THE EYES OF ANIMALS

◆ Does *Lagurus luteus* have colour vision?

O Y Orlov (Institute for Information Transmission Problems, Russian Academy of Sciences, Bolshoy Karetnyi 19, 127994 GSP-4 Moscow, Russia; e-mail: ochakovo@iitp.ru)

In most cases, colour vision is related to cones and to the presence of several cone visual pigments, although in some cases it involves rods (eg 'green rods' in anuran amphibians). As colour vision is supposed to have emerged independently in different branches of the vertebrate tree, the cases of acquisition of necessary prerequisites for it may be of interest. Take the example of the 'yellow vole' *Lagurus luteus*: photoreceptor nuclei in its retina belong to two fairly different types, strongly suggesting the presence of two receptor types with spectrally different visual pigments. This species is one of diurnal rodents, which adopted specific habits and features typical for soughs (daylight activity, settlement aggregation, acoustic signalisation, upright alarm pose, specific elevated eye position), though it belongs to the rodent group (*Cricetidae*), distant enough from ancient arid zone dwellers, the ground squirrels (*Spermophilidae*). Ground squirrels definitely possess colour vision, and this increases the interest of further investigation of *L. luteus* as a diurnal rodent that acquired colour vision independently.

◆ Classical conditioning of coloured stimuli in the honeybee, *Apis mellifera*

C Niggebrügge, N Hempel de Ibarra¶, B Komischke, G Lebouille, R Menzel (Institut für Biologie – Neurobiologie, Freie Universität Berlin, Königin-Luise-Strasse 28–30, D 14195 Berlin, Germany [¶ also University of Sussex, School of Life Sciences, Brighton BN1 9QG, UK; e-mail: claudia.niggebruegge@web.de)

Honeybees display an impressive range of behaviours allowing a study of their visual system in detail. Colour vision is trichromatic, based on three photoreceptor types which are sensitive

in the UV (S), blue (M), and green (L) ranges of the spectrum. Bees use colour mostly to recognise flowers and learn it quickly under free-flight conditions. Here we report our success with training fixed bees to colours in a classical conditioning paradigm. Harnessed bees learned to associate a sugar reward with a coloured stimulus and to extend their proboscis to the stimulus in unrewarded tests. Using this proboscis extension response we evinced that bees learned the hue of the rewarded coloured stimuli. They showed colour generalisation, but did not respond to complementary colours. Further, we tested the hypothesis of regional specialisation of bee eye. Colour acquisition was the same in animals with the dorsal and ventral halves covered as in controls exposed with the whole eye to the light stimuli. Using this paradigm, we aim to study further the mechanisms underlying visual perception in bees by electrophysiological and molecular biological techniques.

[CN was funded by a doctoral fellowship of the German Science Foundation (DFG), GL was supported by the DFG through grant nr. LE1809/1-1.]

◆ **Active vision in landmark learning by bumblebees**

O Riabinina, N Hempel de Ibarra, A Philippides, P Husbands, T S Collett (Centre for Computational Neuroscience and Robotics, University of Sussex, Falmer, Brighton BN1 9QG, UK; e-mail: oriabinina@googlemail.com)

When bees and wasps leave the nest to forage, they perform orientation or learning flights. This behaviour includes a number of stereotyped flight manoeuvres mediating the active acquisition of visual information. Here we describe such flights in bumblebees under natural and laboratory conditions when they are close to their nest in the ground. A colony of bumblebees was located under a textured white carpet with an upright black cylinder 10–20 cm from the nest hole. We have concentrated on analysing in detail where the bumblebee looks and what information it might acquire during the very first portion of the flight when it flies in tight circles close to the nest hole and low on the ground. This feature seems to be far less prominent in other wasps and bees whose orientation flights have been described.

[OR is funded by a de Bourcier doctoral fellowship, NH and AP by the EPSRC.]

◆ **Comparative morphology and optics of gastropod eyes (gastropoda: pulmonata: stylommatophora)**

I P Shepeleva (Department of General and Ecological Physiology of Human and Animals, Faculty of Bioecology, I Kant Russian State University, Universitetskaya 2, 236040 Kaliningrad, Russia; School of Engineering and Science, International University of Bremen, D 28759 Bremen, Germany; Department of Cell and Organism Biology, University of Lund, Helgonavägen 3, S 22362 Lund, Sweden; e-mail: ishepeleva@rambler.ru)

A comparative investigation of the morphology and optics of eyes was carried out on terrestrial gastropod snails, differing by light regime of habitats—*Arion rufus*, *Perforatella incarnata*, *Helicigona lapicida*, and having similar light preferences—*Arianta arbustorum*, *Cepaea hortensis*. The possibilities of structure and optics of the eyes of *A. rufus*, *P. incarnata*, and *H. lapicida* allow them to function as vision organs. Adaptation to seeing in the environment is directed to achieve a comparatively high visual acuity and adequate sensitivity to available light. The eyes of *A. arbustorum* and *C. hortensis* can function as illumination detectors. Some results obtained were compared with the available literature data on eye structure of marine prosobranch snails—ancestors of terrestrial snails. The basic changes in the eye structure caused by transition of snails in phylogenetic development from aquatic to terrestrial habitat are traced in the direction of thickening of the cornea, acquisition of softer consistence and ellipsoidal form of lenses, and in shortening the distance between the lens and retina to minimally possible. From prosobranch ancestors, snails have inherited the dominant role of lenses in focusing the light and gradient of refractive index of the matter of these lenses.

[Supported by grants from German Foundation Marga und Kurt Moellgaard-Stiftung (T 130/2370/2512/12659/03) and Lund University, Sweden.]

◆ **How do foraging *Papilio* butterflies see polarized light?**

K Yamazato, K Arikawa¶, M Kinoshita¶ (Graduate School of Integrated Science, Yokohama City University, 22-2 Seto, Kanazawa-ku, Yokohama 236-0027, Japan; ¶School of Advanced Science, Graduate University for Advanced Studies, Shonan Village, Hayama, Kanagawa 240-0193, Japan; e-mail: v055274c@yokohama-cu.ac.jp)

Papilio butterflies use colour vision for food search. The retina of *Papilio* contains at least six classes of spectral photoreceptor. Each spectral photoreceptor is sensitive to polarised light with specific e-vector angle. Such a retinal organisation might allow the butterflies to see differently polarised lights as different colours. Is it true? We first presented two polarised lights, one horizontally (H) polarized

and the other vertically (V) polarised, to newly emerged *Papilio* butterflies and observed their selection. The test showed that *Papilio* innately prefers V to H. It was very difficult to train *Papilio* to H, so we trained them to unpolarised red (UPR). In the test we presented two stimuli side by side. One was always UPR. Another was either UPR, polarised red (PR) or unpolarised orange (UPO). In the test with the UPR – UPR combination, butterflies always selected the brighter one. In UPR – PR combination, the preference to the UPR changed depending on the intensity of UPR. But in UPR – UPO combination, butterflies always selected UPR regardless of its brightness. These results were consistent in the butterflies trained to blue. Taken together, we conclude that the difference of e-vector angle was detected as brightness difference in foraging *Papilio* under the present condition.

◆ **Cast shadows allow for solid objects discrimination in newly hatched visually naive chicks (*Gallus gallus*)**

E Mascalzoni, L Regolin (Dipartimento di Psicologia Generale, Università di Padova, via Venezia 8, I 35131 Padua, Italy; e-mail: elena-emme@yahoo.it)

We investigated the ability to recognise a solid object from the shadow it casts on an opaque screen in a highly visual animal species, the domestic chick, taking advantage of the ecological procedure of filial imprinting. Newly hatched visually naive chicks were exposed for 2 days to a solid object and subsequently required to choose between two 2-D images: the shadow of the familiar object, and the shadow of an object never seen before. In a first experiment, stimuli were selected to maximise differences in their projected shadows, so that they would be easily distinguishable from one another. In the second experiment we used two objects of controlled dimensions, so that the two testing images would differ only by the position of a single element. Moreover, we checked whether motion could facilitate the task: in both experiments half of the chicks were required to choose between shadows cast by static objects, and half to choose between shadows cast by rotating objects. Results showed that chicks are capable of discriminating between familiar and novel objects on the basis of their cast shadows, and that the motion of the solid stimuli affects this process, being especially crucial for discrimination of stimuli that differ minimally.

◆ **Is colour vision utilised for the detection of the bioluminescent colours of the night in fireflies (*Coleoptera: Lampyridae*)?**

A B Lall (Department of Biology, Howard University, Washington, DC 20059, USA; e-mail: alall@howard.edu)

Some families of beetles utilise bioluminescent (BL) optical signaling for sexual communication. In these families, the colours of the BL vary from lime green to lemon yellow to red–orange. Visual spectral sensitivity was determined by recording electroretinograms from the eyes of the beetles and three spectral mechanisms, near-uv, blue, and green/yellow were isolated by selective adaptation. Spectral tuning between green/yellow visual receptors and species BL emission was observed among all species. A correspondence between behavioural action spectra of the female response to simulated species male's lemon yellow flash with coloured light stimuli was established in firefly *Photinus pyralis*. Now we report that the blue spectral mechanism has an inhibitory effect on the green/yellow mechanism for the detection of species bioluminescence. These findings would suggest the presence of colour vision in fireflies. Whether fireflies utilise colour vision for the detection of conspecific flash is still an open question.

◆ **Bees use relational learning rules in colour learning tasks**

M Wicklein, R B Lotto (Department of Visual Science, University College London, 11–43 Bath Street, London EC1V 9EL, UK; e-mail: m.wicklein@ucl.ac.uk)

A key function of colour vision is to recognise surface colours under multiple lights ('colour constancy'). Recent evidence suggests this is achieved by actively encoding spectral relationships between surfaces that bees experienced under multiple lights. Here we consider what happens if bees only experience surfaces under a single, unchanging light. As there is no 'environmental noise' under these conditions (where the statistical relationship between stimulus and reward is unity), we were interested to know whether bees would learn to use superfluous relational information, or absolute receptor activation values of rewarding stimuli, which would be the most computationally efficient strategy under the conditions used here. First we show that bees were able to correctly identify a 'target' flower colour amongst seven differently coloured non-target flowers under one unchanging illumination. In determining how they solved this problem, we analysed both the 'correct' and highly systematic 'incorrect' flower choices. The data suggest that even under the highly constrained conditions used here, bees relied on a relational brightness strategy, supporting the view that bees use empirical ranking to resolve 'colour constancy', and that

their visual processing is innately biased towards behavioural robustness rather than computational efficiency.

[Supported by the Leverhulme Foundation F/07 134/AW]

◆ **Vernier acuity in barn owls**

W M Harmening, K Goebels, H Wagner (Department of Zoology and Animal Physiology, RWTH Aachen University, Kopernikusstrasse 16, D 52056 Aachen, Germany; e-mail: wolf@bio2.rwth-aachen.de)

We investigated monocular and binocular Vernier thresholds in a highly specialised avian visual system. Thresholds were obtained psychophysically in three adult barn owls (*Tyto alba pratincola*) by an adaptive up-down interleaved staircase procedure with a positive feedback reinforcement schedule. In a 2AFC paradigm the owls had to discriminate between leftward and rightward horizontal Vernier shifts presented in a single pair of vertical bars as well as in a sinusoidal vertical grating. Both stimuli were displayed at high contrast under monocular and binocular viewing conditions. We find a mean displacement angle threshold as low as 4.4 min of arc ($6.8 \text{ cycles deg}^{-1}$) over all animals and conditions. This finding is in agreement with the known theoretical visual acuity estimate derived from retinal ganglion-cell density in that species.

◆ **The contribution of colour to visual memory performance in the non-human primate**

S Liebe, N K Logothetis, G Rainer (Department of Neurophysiology, Max Planck Institute for Biological Cybernetics, Spemannstrasse 38, D 72076 Tübingen, Germany; e-mail: sliebe@tuebingen.mpg.de)

Although objects can be identified solely on the basis of information provided by their spatial structure, colour adds another perceptual dimension which may facilitate object identification. Here, we ask whether colour in natural images is associated with improvements in visual memory performance. We degraded coloured and achromatic natural images with increasing amounts of achromatic noise. At a given degradation level, the difference between coloured and achromatic images was thus provided only by the remaining colour. In a delayed matching-to-sample paradigm a sample stimulus at various degradation levels was presented, followed by an undegraded probe stimulus after a delay period. A lever press was required if the sample stimulus matched the probe stimulus. Preliminary results from one monkey show that visual memory performance decreased as a function of noise level for both colour and achromatic conditions. In addition, we found that the recognition performance was significantly higher for the colour condition than the achromatic condition at the same degradation level ($p = 0.003$, $N = 14$). Since spatial information for both stimulus versions was equally degraded, these results suggest that colour, independently of spatial composition, is associated with an advantage in visual memory performance in the awake behaving primate.

◆ **Extracorneal projection of retinian biopotentials in some *Drosophila* mutants**

D-E Creanga (Faculty of Physics, Biophysics and Medical Physics, University 'Al. I. Cuza', 11A blvd Carol I, RO 700506 Iasi, Romania; e-mail: dorinacreanga@yahoo.com)

Complementary studies on the human eye can be carried out by using indirect data provided by the investigation of the compound eye of the model organism *Drosophila melanogaster*. The parallel organisation, though with a more limited set of neurons than in the case of vertebrates, the spectral sensitivity, the accessibility of the electrophysiological measurements, and the large array of potassium ion channels sustain the utility of the investigation of this alternative visual system. The large variety of *Drosophila* mutants, including those with photoreception peculiarities, makes it interesting from the genetic viewpoint. The biochemical pathway of the pigment was taken into account since *Drosophila* eye contains two classes of pigments: ommochromes and pteridines; however, eye colour also depends on three genes involved in the transport of pigment precursors to the eye. This research is focused on the study of the extracorneal projection of the biopotentials generated within the fruitfly eye by means of the electroretinographic recordings, made on the red-eyed strain as well as yellow- and white-eyed mutants. Single light flash and intermittent illumination were applied. Different levels of light intensity were used to evidence the putative implication of the eye pigment in the electric activity of the retina.

◆ **Rapid visual categorisation of natural images in macaque monkeys is orientation invariant**

M Fabre-Thorpe, G Richard, M Boidot, D Fize (Centre de Recherche Cerveau et Cognition, UMR 5549, CNRS – Université Paul Sabatier, Faculté de Médecine de Rangueil, F 31062 Toulouse Cedex 9, France; e-mail: Michele.Fabre-Thorpe@cercu.ups-tlse.fr)

In humans, categorisation performance in rapid visual presentation tasks is remarkably resistant to image inversion and robust to changes of image orientation. Here, we tested the ability of monkeys to perform a categorisation task on rotated images. Two macaques were trained to

quickly release a button when an animal was present in a natural scene flashed for 30 ms. The 750 square photographs were presented randomly upright or rotated 90°, 180°, or 270°. Twenty novel images were introduced per session during 10 days, and the final session consisted of an entirely novel set of stimuli that the monkeys had never seen before. Monkeys achieved an overall performance of 86% with a mean reaction time of 340 ms, and a minimum reaction time of 240 ms; performances were higher for familiar images than for novel ones. No significant difference in performance was observed between upright and rotated novel images; a slight RT increase was seen with rotated familiar stimuli. The processing underlying the categorisation of animals in natural scenes is thus remarkably orientation-invariant. This rapid categorisation task does not require any time-consuming process involving mental rotation, and does not seem to depend on the global distribution of orientations within the image.

[Supported by the CNRS, Université Paul Sabatier.]

◆ **Prototype effects without peak shift in pigeons**

M M Steurer, D Seebacher, U Aust, M Loidolt, L Huber (Department for Neurobiology and Behavioral Sciences: Emerging Focus Biology of Cognition, University of Vienna, Althanstrasse 14, A 1090 Wien, Austria; michael.steurer@univie.ac.at)

A preference for prototypical stimuli may not only emerge through generalisation from the abstracted central tendency (the prototype) of the stimulus classes, but may also be due to a 'peak shift' of maximum responding. Here, we investigated whether a peak-shift mechanism or an actual prototype effect is responsible for the preference of pigeons for prototypical visual patterns. Furthermore, the influence of different variables, such as the number of training stimuli, stimulus variability within classes, the distance between classes, and the presence of an obvious shape as feature on the occurrence of a 'real' prototype effect was examined. Pigeons were trained to discriminate between two sets of artificial stimuli ('checkerboard pattern'), constructed by random distortions of two prototype patterns. We found evidence for a prototype effect in the absence of a peak shift, which depended on the distance of the exemplars from their own prototype with larger distances leading to larger prototype effects. When the stimulus structure of one class contained an obvious form that could serve as an explicit feature, no prototype effect was found.

[Supported by Austrian Science Fund grant P17157-B03.]

◆ **Haze, clouds, and a restricted field of view: Can crickets make use of their polarisation compass under unfavorable sky conditions?**

M J Henze, T Labhart (Zoological Institute, University of Zürich, Winterthurerstrasse 190, CH 8057 Zürich, Switzerland; e-mail: miriam.henze@zool.unizh.ch)

Field crickets (*Gryllus campestris*) are able to detect the oscillation plane (e-vector) of polarised light. Like other insect species, they presumably use this sense to exploit the celestial polarisation pattern for navigation. Polarisation vision in crickets can be tested by eliciting a spontaneous orientation response: Tethered animals treadmilling on an air-suspended ball adjust their turning tendency according to the e-vector orientation of a polarised light stimulus presented from above. In previous studies, a strongly polarised wide-field stimulus (degree of polarisation $d \sim 100\%$; field of view $f = 83$ deg) was used to induce this reaction. However, the degree of polarisation in the natural sky does not exceed 75% even on clear days and it is much lower if haze or clouds are present. Furthermore, field crickets live on meadows where the observation of the sky is limited by the surrounding vegetation. We have therefore investigated the threshold for the behavioural response to polarised light in crickets under conditions similar to those experienced by the animals in nature. Our results indicate that crickets can rely on their polarisation compass for navigation even under unfavorable sky conditions ($d = 3\%$ to 6% , $f = 1$ deg).

[Supported by the Studienstiftung des Deutschen Volkes.]

◆ **Opsin expression in the eyes of *Heliconius erato***

G Zaccardi, A Kelber, M P Sison-Mangus¶, A D Briscoe¶ (Vision Group, Department of Cell and Organism Biology – Zoology, Lund University, Helgonavägen 3, S 22362 Lund, Sweden; ¶ Comparative and Evolutionary Physiology Group, Department of Ecology and Evolutionary Biology, University of California at Irvine, Irvine, CA 92697, USA; e-mail: guillermo.zaccardi@cob.lu.se)

The requisite for colour vision is the assessment of at least two inputs (receptors) with different spectral sensitivities. The opsin-based visual pigment expressed in these receptors mostly defines their sensitivity. In a recent paper, we demonstrated through behavioural experiments that the nymphalid butterfly *Heliconius erato* discriminates colours in the long-wavelength range (590 nm, 620 nm, and 640 nm). Since the known L, M, and S opsins found in this species (L receptor peak sensitivity 570 nm) are not sufficient to explain this, we started to search for a second L opsin.

This search was not successful. To our surprise, a new S2 opsin that is co-expressed with the already described S1 opsin was found. The in-situ hybridisation performed on the eyes of *H. erato* revealed that the L opsin expresses in six of the eight cells. The remaining two cells expressed S1, S2, and M opsins. Three classes of ommatidia expressed either S in both, M in both, or each opsin in one of the receptors. The distribution of these two types of ommatidia does not show any dorso-ventral differences.

◆ **Participation of chromatic channels in lightness discrimination in cats**

A Kezeli, M Khomeriki, N Lomashvili, Kh Sidamonidze (Laboratory of Vision Physiology, I Beritashvili Institute of Physiology, Georgian Academy of Sciences, Tbilisi 0160, Georgia; e-mail: akezeli@gmail.com)

The aim of our investigation was to confirm that the chromatic channels of cat's visual system are involved in lightness discrimination. Three cats were trained to discriminate achromatic stimuli by their lightness under 'white' illumination (100 W incandescent lamp). After achievement of a statistically significant level of 'light-dark' differentiation we replaced achromatic stimuli with 'red-green' or 'blue-yellow' pairs. The stimuli in the pairs had randomly changed colour/lightness combinations. The red-green pair was illuminated with a mixture of red and green light, and the blue-yellow pair with a mixture of blue and yellow light. With an increase of the red component in mixed light, the red stimulus becomes lighter than the green one, and with an increase of the green component the green stimulus becomes lighter. Correspondingly, under blue illumination, the blue stimulus becomes lighter, while under yellow illumination the yellow stimulus becomes lighter. With some red-green and blue-yellow mixtures of light it becomes impossible to discriminate stimuli by their lightness. We have shown that, for cats, stimuli remained indistinguishable under broadband changes of red-green light combination, while performance was strongly impaired with small changes of blue-yellow combination. It seems that lightness information processing take place in colour channels of the visual system of cats, and it occurs differentially in different channels.

◆ **A private communication channel for coral reef fish based on UV signalling**

U E Siebeck (School of Biomedical Sciences, University of Queensland, Brisbane, QLD 4072, Australia; e-mail: u.siebeck@uq.edu.au)

In contrast to their freshwater and deep-sea counterparts, coral reef fish are extremely colourful. Many possess ultraviolet (UV) colour patterns invisible to humans and many predatory fish. The behavioural significance of these patterns was studied here. In the first experiment, the response of *Pomacentrus amboinensis* males towards a choice of two conspecific intruders was tested. One intruder was presented in a UV-transmitting (UV+) container and the other in a UV-absorbing (UV-) container. Territory owners attacked intruders viewed through UV+ filters significantly more vigorously than those seen through UV- filters, revealing that the males are sensitive to UV light and that they modified their behaviour on the basis of the visibility of UV patterning. In the second experiment, the response of *Pomacentrus amboinensis* males was tested towards a conspecific intruder and a heterospecific intruder possessing similar general appearance but a markedly different UV facial pattern. Conspecifics were preferentially attacked in UV+ conditions but not under UV- conditions. Taken as a whole, the two experiments strongly support the hypothesis that UV light has an important impact on behaviour. Communication in the UV may represent an effective solution to the age-old evolutionary conflict between being conspicuous to conspecifics and inconspicuous to predators.

[Supported by the Australian Research Council.]

◆ **Group dynamics in the hunting behaviour of archerfish (*Toxotes chatareus*): A laboratory analysis**

M Pollirer, W Apfalter, I H Machatschke, L Huber (Department for Neurobiology and Behavioral Sciences, University of Vienna, Althanstrasse 14, A 1090 Vienna, Austria; e-mail: michael.pollirer@hotmail.com)

The archerfish (*Toxotes sp.*) represents an outstanding model for visual research in that this animal has to compensate for the different optical features of water and air when hunting air-borne prey by shooting (ie, ejecting water-streams) or by jumping from below the surface of the water. These foraging strategies heavily rely on visual capacities such as change-perception, motion perception, or object recognition. Individual shooting behaviour has already been described extensively, but with regard to group dynamics, little information is available. In the present work, we investigated hunting behaviour in a social context. To this end, a group of seventeen fish was presented with live flies in a laboratory setup. Hitting rate, different prey-catching strategies, and shooting performance were recorded. Although individual differences

were quite strong, it turned out that conspecific aggression, behaviour of initial shooters (ie subjects that predominantly started shooting sprees) and distance of prey to the water surface had all considerable influence on hunting behaviour. In addition, movement of prey proved to be essential for detection and motivation to continue hunting while speed of prey limited the hitting rate.

◆ **Categorical versus dimensional perception of human faces by pigeons determined by a multiple-matching procedure**

W Apfalter, M M Steurer, N F Troje¶, L Huber (Department for Neurobiology and Behavioral Sciences: Emerging Focus Biology of Cognition, University of Vienna, Althanstrasse 14, A 1090 Vienna, Austria; ¶ Department of Psychology, Queen's University, Kingston, Ontario K7L3N6, Canada; e-mail: wilfried.apfalter@univie.ac.at)

Employing a multiple-matching procedure (Huber et al, 2005 *Journal of Experimental Psychology: Animal Behavior Processes* 31 237–246) we investigated whether pigeons show the typical characteristics of categorical perception when discriminating gray-scale images of human faces according to sex. Tests with morphed face images (hybrids between a male and a female face) and different amounts of familiarisation revealed that the pigeons' strategies actually incorporated features of both dimensional and categorical perception. Scrambling and inversion of the stimuli both led to a decrease in performance, which suggests that those picture manipulations impeded access to some though not all sources of relevant information.

[Supported by Austrian Science Fund grant P17157-B03.]

OPTIC FLOW

◆ **The flow parsing hypothesis: Control studies supporting a new role for optic flow**

P A Warren, S K Rushton¶ (Centre for Human Sciences, QinetiQ Ltd, Ively Road, Farnborough GU14 0LX, UK; ¶ School of Psychology, Cardiff University, Tower Building, Park Place, Cardiff CF10 3AT, UK; e-mail: pawarren@qinetiq.com)

Successful interaction with the world during self movement requires knowledge of when objects in the scene are moving and where they are going. Answering these questions by means of only retinal motion is difficult, since it can result from movement of the observer, an object, or both. On the basis of the results of several studies we have suggested that the brain solves this problem by 'parsing out' optic flow (OF); remaining retinal motion can then be attributed to object movement. Control studies were undertaken to further test this flow-parsing hypothesis. Stationary observers viewed stimuli containing non-stereo or stereo motion information consistent with self movement in three experimental paradigms: (i) detection—observers identified scene-relative object movement as quickly as possible; (ii) trajectory—observers indicated target trajectory relative to the scene; (iii) visual search—observers indicated a scene—moving target amongst scene—stationary distractors. The results indicate that local target—background interactions cannot account for observed data (suggesting a global mechanism such as OF processing is responsible), and that stereo OF information is important for flow parsing. This work supports an emerging role for OF processing in the identification and estimation of scene-relative object motion during observer movement.

◆ **The effect of noise and prism adaptation on optic flow**

R Daini, F Saibene, G Pagnotta, R van der Zwan¶ (Department of Psychology, Università degli Studi di Milano-Bicocca, via dell'Innovazione 10, I 20126 Milan, Italy; ¶ School of Psychology, Southern Cross University, Hogbin Drive, Coffs Harbour, NSW 2457, Australia; e-mail: roberta.daini@unimib.it)

In line-bisection task, normal observers erroneously locate the midpoint to the left of the veridical centre (pseudoneglect). This effect is modulated by prism adaptation. Pseudoneglect may be due to a misperception in the horizontal visuo-spatial plane, independent from the specific demands of the task. To assess this conjecture and draw inferences on the possible physiological mechanisms involved, we used a dynamic paradigm with optic flow field as stimulus. We measured the perceived midpoint of origin of an expanding optic flow field in a 2AFC task. In experiment 1, we added noise to each hemispace in order to simulate the consequences of a contralateral brain lesion. Observers showed a slight leftward bias (as pseudoneglect phenomenon) in the perception of the origin of an optic flow field. Moreover, the noise on the left induced a significant rightward shift, as a right parietal lesion does. In experiment 2, we tested the effect of prism adaptation to both sides of space and observed asymmetrical shifts. The lateralised shift observed in the line-bisection task is also present for dynamic stimuli, suggesting that the effect is due to a more general asymmetry in the perception of the horizontal spatial plane.

◆ **Estimating heading and collisions with the environment from curvilinear self-motion in optical flow patterns**

P Bayerl, H Neumann (Department of Neural Information Processing, University of Ulm, Oberer Eselsberg, D 89069 Ulm, Germany; e-mail: pierre@neuro.informatik.uni-ulm.de)

Spatial navigation along curvilinear paths generally induces optic flow fields with superimposed translational and rotational components. While mathematical methods have been developed to segregate these two components apart, little is known how human observers deal with this separation. Here, we investigate the ability to predict collisions with the environment in the presence of curvilinear self-motion. We investigate the perceived tangential direction of movement and the temporal course of the subjects' estimation of the point of collision with a wall in the environment. The subjects' gaze is utilised to indicate the current estimation (SMI-HiSpeed Eyetracker). In comparison with estimating the tangential direction of self-motion, the estimation of the point of collision is highly perturbed by rotational components. The temporal analysis of estimating the observer's point of collision revealed that in the presence of rotational self-motion many gaze corrections are necessary until the observer reaches the location where he expects hitting the wall. Without rotation only few saccades are necessary. We conclude that the estimation of collision points in optic-flow-based heading requires corrective visual input updates in the case of rotational self-motion, and suggest that the visual system utilises predictive compensations mediated via feedback from high-order stages of neural decision making.

[Supported in part by a grant from the European Union to Heiko Neumann (EU FP6 IST Cognitive Systems Integrated project: Neural Decision-Making in Motion; project number 027198).]

◆ **Superimposed uniform motion shifts the focus of a contracting optic flow field less than the focus of expansion**

J Duijnhouwer, R J A van Wezel, A V van den Berg (Helmholtz Institute, Utrecht University, Padualaan 8, NL 3584 CH Utrecht, The Netherlands; e-mail: j.duijnhouwer@bio.uu.nl)

The focus of an expanding optic flow field appears to be shifted in the direction of superimposed uniform flow. In this study, we measured the analogous effect in contracting optic flow fields. We find that the shift is much smaller for contraction. In the literature, this illusion has been explained at a global level in terms of a mechanism that removes the effect of eye rotations on expansional flow. This mechanism is assumed to be (erroneously) triggered by the uniform flow. Alternatively, the shift has been explained by local motion induction. In that account, the overlapping flow vectors are subtracted from the expanding flow vectors, yielding the focus shift. Our result suggests that the eye rotation compensation is unequal for expansion and contraction, or that local motion induction is different for motions away from and towards the fovea.

◆ **Forward and backward self-motion distort perceived heading during eccentric viewing along opposite directions**

Z Fan, J P Harris (School of Psychology and Clinical Language Sciences, University of Reading, Reading RG6 6AL, UK; e-mail: z.fan@reading.ac.uk)

Three experiments were carried out simulating an observer's self-motion towards and away from a frontoparallel surface with controlled fixation and peripheral viewing. The task was to judge whether a target bar was to the right or left of the heading. In experiment 1, we found a significant interaction between flow type (expanding or contracting optic flow) and direction of offset of the target bar from the heading (nearer to or further away from the fixation point), suggesting a direction difference in the drift of perceived heading between forward and backward self-motion. This was confirmed in experiments 2 and 3: with eccentric viewing, expansion (forward self-motion) shifts perceived heading away from the fixation, while contraction (backward self-motion) shifts perceived heading towards the fixation. Experiment 3, in which display element life-times were shortened, demonstrated that these drifts of perceived heading, resulted from global processing of the display. No significant heading threshold differences between expansion and contraction were found. We suggest that heading drifts result from anisotropic sensitivities to different directions of motion—a centripetal bias, and discuss the results in the context of interactions between two subsystems in motion perception: the processing of motion direction and the encoding of spatial location.

◆ **Change detection with looming and receding stimuli**

S G Havanur, N Srinivasan (Centre for Behavioural and Cognitive Sciences, University of Allahabad, Allahabad 211002, India; e-mail: setugh@rediffmail.com)

Change detection is important for various tasks and most experiments have focused on changes to static objects. We conducted two experiments which explored the relationship between change detection and motion (looming or receding) by measuring change detection capacity for orientation

and colour change. The results indicate an asymmetry in change detection, depending on expansion or contraction of optic flow, but only for orientation and not for colour. In both experiments, a change to one of the stimuli was to be detected in a looming or receding display with multiple stimuli. The display consisted of twelve rectangular bars (experiment 1) or coloured discs (experiment 2) arranged in a circular fashion. In experiment 1, there was a change in orientation of the rectangular bars in half the trials mid-way through looming or receding. In the other half of the trials, no change was made. Observers detected the change better among looming stimuli compared to receding stimuli. In experiment 2 we measured accuracy of change detection with colour. Unlike experiment 1, no significant advantage in change detection was observed with looming stimuli compared with receding stimuli. This difference can be explained by the effectiveness of change detection for further actions.

HEADING AND ORIENTING IN VISUAL SPACE

◆ Mapping auditory instructions onto gaze trajectories: How attention is guided by driver-assistant systems

H Koesling, R G Reilly (Department of Computer Science, National University of Ireland, Maynooth, Co. Kildare, Ireland; e-mail: hendrik@cs.nuim.ie)

Following navigation instructions is a common task in automotive environments. We investigated how auditory instructions and visual information are integrated in order to accomplish this task. Subjects had to follow spoken navigation instructions while viewing animated traffic scenes. Linguistic and visual factors showed significant effects on instruction comprehension. Oculomotor data and the distribution of visual attention reflected this visuo-linguistic interaction, indicating how drivers process navigation instructions in dynamic situations. Whereas vehicular traffic and relevant road furniture were mostly attended to before and after messages were issued, visual attention shifted to areas that were verbally referred to during message issuing. The visual focus was guided by instructions, but also took into account additional scene information. The serial mapping of verbally referred-to scene objects onto gaze points could not always be maintained. Complex instructions, busy traffic, and redundant verbal information particularly compromised the integration of auditory and visual information. Apparently, a tight synchronisation of auditory and visual input is required for accurate message comprehension. If this process is disturbed, message comprehension in dynamic environment deteriorates. On the basis of the empirical findings, we have started to implement a computational model that attempts to simulate the sequential mapping of navigation instructions onto gaze trajectories.

◆ Perceptual constraints of navigation and object manipulation in virtual environments

A Huckauf (Faculty of Media, Bauhaus-University Weimar, Bauhausstrasse 11, D 99423 Weimar, Germany; e-mail: anke.huckauf@medien.uni-weimar.de)

Behaving in virtual environments requires the ability to move. Movements are performed by input devices. Regarding the design as well as the control and usability of necessary 3-D devices there are still several open questions. This investigation covered various modes of control for navigation (ie controlling the view) as well as for object manipulation (ie controlling things in virtual environments). Whether navigation is advantageously implemented in person-centred or in object-centred coordinates depends on the available visual room: The person-centred 'flying' mode was faster and better within a scene, whereas object-centred navigation was better when an object was presented before a homogeneous background. A second series of experiments revealed that objects can be manipulated better when the coordinates of the device are the same as the coordinates of the person relative to the object or the room.

◆ Active gaze, visual look-ahead and locomotor control

R M Wilkie, J P Wann¶ (Institute of Psychological Sciences, University of Leeds, Leeds LS2 9JT, UK; ¶ School of Psychology, University of Reading, Earley Gate, Whiteknights, Reading RG6 6AL, UK; e-mail: r.m.wilkie@leeds.ac.uk)

Previously we examined the use of active exploratory gaze when steering along a roadway (Wilkie and Wann, 2003 *Journal of Vision* 3 677–684). Here we studied how gaze is used in open-field steering when attempting to negotiate a series of slalom gates. This task requires forward planning to ensure current steering carries you via the immediate gate without precluding safe passage through future gates. Since our head and eyes can only be directed towards one location at a time, we predicted competition for gaze resources between the current gate (G_n) and the next one (G_{n+1}). Initially we examined where participants looked whilst steering the slalom course. We then disrupted natural gaze patterns and forced participants to move their gaze to G_{n+1} earlier or later than they would normally. We also examined whether participants monitored their current target alignment through peripheral vision or some form of visual-spatial buffer. Results indicate

that active gaze has a powerful role in controlling locomotion, but that there are also other useful sources of information, and stored representations that aid locomotor control. We discuss the relationship between gaze shifting and steering performance with reference to our active gaze model of steering.

[Supported by the UK EPSRC GR/S86358 & EP/D055342/1.]

◆ **Cognitive task could prevent deterioration of brain activity during prolonged driving on monotonous motorway**

M Ohmi (Human Information System Laboratory, Kanazawa Institute of Technology, 3-1 Yakkaho, Hakusan, Ishikawa 924-0838, Japan; e-mail: ohmi@his.kanazawa-it.ac.jp)

It is known that sleepiness while driving a car on a monotonous motorway is a cause of car accidents. Since it is assumed that sleepiness can be objectively estimated by measuring the deterioration of brain activity, we measured observers' brain activity by near-infrared spectrometry (NIRS) while they were driving on a simulated monotonous motorway. We found that brain activity of ten observers deteriorated gradually and reached an asymptote after 10 min of driving. In order to investigate ways of preventing deterioration of brain activity during prolonged driving, we imposed a cognitive task on the observers and measured their brain activity. A small target was flashed ten times with a 20 s interval after 5, 10, and 25 min. It was presented either to the right or to the left of the centre of the screen. Observers were instructed to make a saccade in the opposite direction. We found that five of ten observers made a correct saccade and their brain activity measured by NIRS did not deteriorate. But the brain activity of the other observers deteriorated gradually. These results suggest that imposing an appropriate cognitive task during prolonged driving on a monotonous motorway could be useful for preventing car accidents caused by sleepiness.

◆ **Effects of relative object size on perceived distance and time-to-collision under monocular viewing**

M Hofbauer, T Eggert (Department of Neurology, Ludwig Maximilians University Munich, Marchioninistrasse 23, D 81377 Munich, Germany; e-mail: mhofbauer@nefo.med.uni-muenchen.de)

From previous experiments (Hofbauer and Eggert, 2005 *Perception* **34** Supplement, 110), we suggest that perceived object speed in depth is derived from retinal velocity signals, scaled by perceived distance. In the present study, a two-lane road and three cars in front of the observer were presented in a perspective projection on a silver screen. Perceived distance was manipulated by scaling the width of the road and the size of the cars, while the target in the oncoming lane remained unchanged. (i) We examined if the change in perceived distance affects perceived object speed and time-to-collision in a stationary environment as predicted by our previous hypothesis. (ii) We investigated how means and standard deviations of perceived distance and time-to-collision were affected during simulated self-movement. With the stationary environment as well as with simulated self-movement, we observed a shorter time-to-collision response while the object appeared further away from the observer with the scaled scene. Therefore, the suggested hypothesis is consistent with the experimental results. Means and standard deviations did not differ significantly between the stationary and simulated self-movement conditions neither for perceived distance nor time-to-collision.

[Supported by the Bayerische Forschungsförderung (FORBIAS).]

VISION AND ACTION

◆ **Manual asymmetries in visually guided pointing of right-handers and left-handers**

B F M Marino, N Stucchi (Department of Psychology, Università di Milano-Bicocca, 1 piazza dell'Ateneo Nuovo, I 20126 Milan, Italy; e-mail: barbara.marino@unimib.it)

Some advantages, such as greater end-point accuracy and shorter duration, have been found for movements made by the hand to ipsilateral targets when compared with movements to contralateral targets of equivalent eccentricity and direction. An experiment was conducted to investigate the suggestion that the advantages for ipsilateral movements are more marked in the right hand of right-handers (Carey et al, 1996 *Experimental Brain Research* **112** 496–504), but not in the left hand of left-handers (Velay and Benoit-Dubrocard, 1999 *Neuropsychologia* **37** 895–903). Ten right-handers and ten left-handers were required to perform pointing movements with their right or left hand towards the mirror image of visual targets presented on a touch-screen at three possible eccentricities (1.5, 6, and 12 cm) to either the right or to the left of a central fixation point. Both a greater end-point accuracy and a shorter duration were found for ipsilateral movements performed at maximum eccentricity. The advantage in end-point accuracy was more marked for the right hand

of right-handers. The modulation of the advantages for ipsilateral movements by target eccentricity supports the idea that these manual asymmetries result from biomechanical constraints of the arm rather than from more efficient within-hemisphere visuomotor transformation.

◆ **Grasping: A stereotyped visuomotor pattern?**

C Hesse, V H Franz (Department of Experimental Psychology, Justus Liebig University Giessen, Otto-Behaghel-Strasse 10F, D 35394 Giessen, Germany; e-mail: constanze.hesse@psychol.uni-giessen.de)

When grasping objects with a precision grip, index finger and thumb open gradually to a maximum grip aperture (MGA) which occurs in the second half of the movement and is influenced by several factors such as object size and target visibility (Jeannerod, 1984 *Journal of Motor Behavior* **16** 235–254; Hu et al, 1999 *Experimental Brain Research* **126** 109–116). However, we still have little knowledge about how grasping is controlled by the nervous system. We therefore investigated the characteristics of the grip aperture under different conditions. In experiment 1, we examined the effect of object size (39, 41, 43 mm) on aperture in different visibility conditions reducing the amount of visual feedback available during grasping: full vision, full vision until movement initiation, full vision until start signal, and 5 s delay (visual occlusion for 5 s before movement initiation). In experiment 2, participants grasped a variety of object sizes (1–10 cm) under full vision. Results show that MGA was determined by object size and the availability of visual feedback as predicted. Nevertheless, the aperture profiles of the different conditions showed similar characteristics. We suggest a very simple model of grip aperture which may account for most of the observed changes in aperture and evaluate the appropriateness of the model.

[Supported by DFG grant FR 2100/1-1.]

◆ **A study of visual target image representation during reaching and grasping toward a Müller-Lyer object**

T Hayashi, Y Tatsuno¶, T Inui§ (Faculty of Informatics, Kansai University, Takatsuki-shi, Osaka 569-1095, Japan; ¶ Hewlett-Packard Japan Ltd, Shinagawa, Tokyo 140-8641, Japan; § Graduate School of Informatics, Kyoto University, Kyoto 606-8501, Japan; e-mail: hayashi@res.kutc.kansai-u.ac.jp)

In the planning-control model for reaching and grasping actions, separate target image representations are assumed to be used in the motion planning and online-control systems (Glover, 2004 *Behavioral and Brain Sciences* **27** 3–24). The aim of the present research is to validate the model and to clarify the interactions between the two systems. In the experiment, real (wooden cylinder) objects and virtual (binocular stereo CG-image) objects of the Müller-Lyer shape were used as reaching/grasping targets. Subjects were asked to reach for and grasp the objects and the reaching distance and grip aperture size were measured by magnetic sensors at 240 Hz. Ten university students participated in the experiment. For both real and virtual objects, the maximum grip aperture size was affected by the illusion, implying that the illusion affects the planning system in the early stage of grasping. In a follow-up experiment, the virtual object suddenly disappeared during reaching when the subject's hand came within a certain distance, Δ . The results show that the final grip aperture size was affected by the illusion. As Δ becomes large, the influence of the illusion becomes gradually smaller. We conclude that the interactions between the planning system and the control system occur continuously during reaching/grasping movements.

[Supported by Grants-in-Aid for Scientific Research from JMEXT(No.16300085).]

◆ **Linguistic and spatial cue for action**

Y Coello, A Weisbecker (URECA, University of Lille, F 59653 Villeneuve d'Ascq, France; e-mail: yann.coello@univ-lille3.fr)

There is converging psychological and neurophysiological evidence for a dissociation of vision into a ventral and a dorsal stream with distinct object attribute processing for perception and recognition or action. However, it appears obvious that motor behaviour can be triggered according to linguistic (processed within the ventral stream) or spatial (processed within the dorsal stream) cue but with different time constraints owing to differences in the magno/parvocellular neural latencies. We tested the influence of presenting a congruent or incongruent spatial cue when processing a linguistic cue (or the opposite) to specify a right or left motor response. We found no interference effect (spatial accuracy and RT) when responding according to the spatial cue (target-dot to the right or left side of a rectangular frame), whatever the linguistic cue ('droite' or 'gauche' word within the frame). As opposed to this, a strong interference effect of spatial cue was found when responding according to the linguistic cue but only at a short reaction time (300 to 400 ms). Movement selection can thus be influenced by nonrelevant cue suggesting that ventral and dorsal streams are activated simultaneously and compete to specify the relevant visual information for action but with different temporal constraints.

◆ **Perceiving what is reachable: Evidence for visuomotor interactions**

Y Coello, A Deplancke (URECA, University of Lille, F 59653 Villeneuve d'Ascq, France; e-mail: yann.coello@univ-lille3.fr)

Previous studies have suggested that the conscious experience of what is reachable is related to the true limit of action capabilities. Hence, perception of object reachability must depend on interaction between the motor and sensory system. Two experiments are reported whose aim was to evaluate whether modifying the structure of visual space or visuomotor calibration influences the perception of object reachability. In experiment 1, participants were required to determine whether a visual target was reachable or not, or to actually act on it with the right hand. When comparing perceptual and motor performances, we found that the subjective area comprising reachable objects decreased whereas the amplitude of reaching movement increased by the same amount as when providing a textured background instead of a dark background. In experiment 2, recalibrating the visuomotor system by providing a bias visual feedback of ± 4 cm modified the perception of what is reachable. Thus, perception of object reachability relies, at least to a certain extent, on preparatory motor activity or action simulation. The function of the simulation process would be not only to shape the motor system in anticipation of execution, but also to provide the self with information on the feasibility of potential actions that is used for perceptual spatial categorisation.

◆ **Interference between two opposing visuomotor rotations varies depending on the level of separation in motor workspace**

D G Woolley, J R Tresilian, R G Carson, S Riek (Perception and Motor Systems Laboratory, University of Queensland, Brisbane, QLD 4072, Australia; e-mail: dwoolley@hms.uq.edu.au)

We investigated the extent to which two opposing ($\pm 70^\circ$) visuomotor rotations interfered with one another in a dual-adaptation paradigm. Flexion/extension torques imparted on a manipulandum were represented on a visual display by movement of a cursor in the vertical direction and supination/pronation torques in the horizontal direction. Subjects moved the cursor to target sets presented in opposite quadrants of the display in the visual workspace. The rotations associated with each target set resulted in all targets being acquired by a combination of flexion and pronation torques, with varying degrees of separation in the motor workspace depending on the specific target. The extent of adaptation to each visuomotor rotation, measured by assessing the level of performance improvement in the training block and the size of the aftereffect in the post block, varied depending on the degree of separation between targets in the motor workspace. Targets with the greatest dissimilarity in terms of their respective muscle recruitment patterns showed near-complete adaptation. Targets with the least separation in motor workspace showed incomplete adaptation, which was significantly less than that observed for targets further apart. Our results indicate that conflict in the motor workspace contributes to interference between opposing visuomotor rotations.

◆ **Grasping 3-D and 2-D targets: No effect of target dimensionality on manual prehension**

L Minini, J Wattam-Bell (Department of Physiology, Anatomy and Genetics, University of Oxford, Sherrington Building, Parks Road, Oxford OX1 3PT, UK; ¶ Visual Development Unit, Department of Psychology, University College London, Gower Street, London WC1E 6BT, UK; e-mail: lori.minini@physiol.ox.ac.uk)

Evidence suggests that visually guided prehension is mediated by dedicated visuomotor mechanisms in the dorsal visual system (Goodale and Milner, 1992 *Trends in Neurosciences* 15 20–25). A question of interest is whether this system only mediates action aimed at 3-D objects, or whether it does not fundamentally distinguish between 3-D and 2-D targets. Westwood et al (2002 *Experimental Brain Research* 144 262–267) reported that a patient with visual-form agnosia could adjust her grip aperture according to the size of 2-D targets, suggesting that dorsal visual processing mediated this response. In agreement with this claim, Kwok and Braddick (2003 *Neuropsychologia* 41 932–940) found no illusion effects on grasping to either 3-D or 2-D targets. However, both groups reported significantly smaller grip apertures for grasps to 2-D stimuli that still remain largely unaccounted for. In this study, we measured grasps to 3-D, 2-D, and 2-D-enhanced versions of the Diagonal illusion. No effects of target dimensionality were observed on maximum grip aperture and maximum wrist velocity. Moreover, equivalent illusion effects were found in all conditions. Taken together, these results suggest that all stimuli engaged similar visuomotor mechanisms and that grasping 2-D targets is likely mediated by dorsal visual processing.

◆ **The role of colour in visually guided actions**

I Ivanov, A M C Werner (Department of Ophthalmology, University of Tübingen Eye Hospital, Röntgenweg 11, D 72074 Tübingen, Germany; e-mail: iliqv@yahoo.com)

Current theories on visual information processing suggest that colour- and action-related information is processed separately in the ventral and the dorsal streams. Each stream codes the

information differently, depending on its use. In this experiment we tested the role of colour in guiding action. Both localisation accuracy and simple reaction times were measured for pointing at 3 deg sine-wave Gabor patches presented at 15° retinal eccentricities. The gratings were modulated along the red–green ($L-M$), blue–yellow ($S-[L+M]$), and luminance ($M+L$) axes in the DKL colour space. Their luminance and chromatic contrast were scaled in term of multiples of detection threshold ($C = 0.04 \times \text{detection threshold}$). All observers had normal colour vision as tested by the Cambridge Colour Test. Within each session (200 trials) subjects were cued to a different visual attribute. In each trail the grating was presented as either isoluminant-colour-defined or luminance-defined. The observers attended and reacted to colour gratings and rejected the moving ones or vice versa. Pointing errors for all stimuli were less than 0.5°; no significant difference in the reaction times was observed for different stimuli driving the pointing behaviour. These findings suggest that colour information is involved in visuomotor control.

[Supported by the Human Resources and Mobility Activity Marie Curie Host Fellowships for Early Stage Research Training under contract “PERACT MEST-CT-2004-504321” by the European Union.]

◆ Grasping completions: Towards a new paradigm

J Lommertzen, R G J Meulenbroek, R van Lier (Nijmegen Institute for Cognition and Information, Radboud University Nijmegen, PO Box 9104, NL 6500 HE Nijmegen, The Netherlands; e-mail: j.lommertzen@nici.ru.nl)

We studied contextual effects of amodal completion in both a primed-matching task, and a grasping task in a within-subjects design with twenty-nine participants. Stimuli were partly occluded cylindrical objects that could have indentations (or protrusions) at regular intervals along the contour. The stimuli were designed so that they could reveal two plausible completions: a local completion, which comprised a linear continuation of the partly occluded contours behind the occluder, and a global completion, which revealed a continuation of the indentations behind the occluder. The results of the primed-matching task, with a prime duration of 500 ms, showed mixed preferences for either global or local completion, confirming the perceptual ambiguity of the occlusion displays. In the grasping task, a partly occluded cylindrical object was projected for 500 ms, after which the participants grasped an invisible cylinder while their grasping kinematics were recorded. The realised maximum apertures reflected whether participants used a global, a local, or an averaged interpretation of the width of the stimulus to guide their grasping response. Again mixed preferences for the various object interpretations were found. Collectively, the data show sufficient sensitivity of our paradigm to investigate the relationship between the perception and grasping of partly occluded objects.

◆ Effects of depth order on visual control of posture and vection are opposite

M Kitazaki, M Mishiroy (Research Center for Future Vehicle and Intelligent Sensing System Research Center [also at ¶ Department of Knowledge-based Information Engineering], Toyohashi University of Technology, 1-1 Hibarigaoka, Tempakucho, Toyohashi 4418580, Japan; e-mail: mich@tutkie.tut.ac.jp)

Optic flow induces postural sway as well as vection. Recently, differences of their processing have been reported [eg Kitazaki and Hashimoto, 2006 *Journal of Vision* 6(6) 149a]. In this study, we investigated the effect of the depth order of moving surfaces on the visually induced postural sway in comparison with vection, which is dominated by visual motion in far depth (eg Brandt et al, 1975 *Perception & Psychophysics* 17 497–503). Two overlapped surfaces of random dots separated by binocular disparity were presented to subjects. In experiment 1, one surface moved horizontally back and forth at 0.2 Hz while the other was constant. In experiment 2, one surface moved along the line of sight (expanding/contracting) back and forth at 0.2 Hz while the other was constant. We measured subjects' postural sway at 60 Hz sampling rate for 50 s presentation. In experiment 3, we presented the identical motions except that the motions were not cyclic but unidirectional, and we measured vection latency. We found that subjects swayed more when the near surface was moving than when the far surface was moving. Vection was, however, stronger when the far surface was moving. These results suggest that the visual control of posture and that of vection are processed at different levels or pathways.

[This research was supported by Nissan Science Foundation and MEXT, Japan.]

◆ Effects of feedback on eye–hand coordination during movement under risk

M Stritzke, A Ma-Wyatt (¶, J Trommershäuser (Department of Psychology, University of Giessen, Otto-Behagel-Strasse 10F, D 35394 Giessen, Germany; ¶ Smith-Kettlewell Eye Research Institute, 2318 Fillmore Street, San Francisco, CA 94115, USA; e-mail: martin.stritzke@psychol.uni-giessen.de)

We investigated whether observers can use different types of feedback to alter their eye–hand coordination during a goal-directed pointing task under risk. The task was to point to a target

region while avoiding an adjacent penalty region. Observers won points (100) if they hit inside the target region, and lost points (0 to 500) if they hit inside the penalty region. Both regions were Gaussian blobs ($\sigma = 0.5$ deg), presented within a region 8–10 deg eccentric to initial fixation. In experiment 1, feedback was provided only for the finger landing position. In experiments 2 and 3, subjects received an additional penalty (100) if their first saccades landed beyond a distance of 1.5 deg relative to the finger end-point, or within a distance of 1.5 deg, respectively. Observers were able to change their eye–hand coordination if additional feedback on eye–hand distance was provided. Experimental data are compared to a model that defines optimal sensorimotor behaviour under these conditions. In the model, optimality is computed on the basis of subjects' motor and saccadic end-point variability, similar to optimal performance as defined for rapid pointing under risk. We discuss parameters of the model as well as how subjects' performance compares to the performance of an optimal observer.

[Supported by Deutsche Forschungsgemeinschaft (Emmy-Noether-Programm, Grant TR 528/1-2). Rachel C Atkinson Fellowship to AMW.]

◆ **Deviation of manual responses toward a to-be-ignored stimulus location: Distractor inhibition revisited**

S Buetti, D Kerzel (Department of Psychology, University of Geneva, 40 boulevard du Pont d'Arve, CH 1205 Geneva, Switzerland; e-mail: simona.buetti@pse.unige.ch)

In reaching tasks, it has been demonstrated that a to-be-ignored visual stimulus can lead to trajectory deviations away from the irrelevant stimulus. The purpose of this study was to investigate how a visual stimulus, task-irrelevant by its location but relevant by its colour, influenced the trajectory of goal-directed movements. Subjects were instructed to perform a leftward or rightward movement to one of two boxes displayed on a flat panel screen. A square appeared in one of the boxes and the colour of the square indicated whether the left or right box had to be touched. Thus, the square could either appear in the box specified by its colour (congruent condition) or in the opposite side box (incongruent condition). Results showed an effect of congruency in reaction and movement times: responses were faster when the response location spatially corresponded to the stimulus position than when it did not. The congruency effect in the movement times was due to a tendency to first start the movement toward the source of stimulation, indicating that subjects were unable to ignore the task-irrelevant stimulus location. The results are inconsistent with accounts claiming that task-irrelevant distractors are inhibited and responses veer away from inhibited locations.

◆ **Reflections on bimanual phase shifting under different visual conditions**

G Buckingham, D P Carey, A Sahraie (Vision Research Laboratories, School of Psychology, William Guild Building, University of Aberdeen, Aberdeen AB24 2UB, Scotland, UK; e-mail: g.buckingham@abdn.ac.uk)

Several studies have shown that asynchronous bimanual movement patterns tend to spontaneously shift to a symmetrical movement pattern at higher frequencies. Little is known about the perceptual influences toward the intended pattern of bimanual movement. Twenty participants were required to make adductive-abductive index finger movements in the horizontal plane when viewing an image of the dominant or the non-dominant hand reflected in a mirror, whilst attempting to make out-of-phase movements. Preliminary analysis suggests that the shift to synchrony happens earlier in mirror conditions compared to control conditions. In spite of the apparent simplicity of this class of movement, these data demonstrate how incongruent feedback of the limb occluded by the mirror influences phase shifting. Possible asymmetries in this effect are also discussed.

[Supported by a 6th century studentship from the College of Life Sciences and Medicine to GB.]

◆ **The specificity of motor control in perceiving the flash-lag effect**

L Scocchia, R A Grosso, G Baud-Bovy ¶, N Stucchi (Department of Psychology, University of Milano-Bicocca, piazza dell'Ateneo Nuovo 1, I 20126 Milan, Italy; ¶ Faculty of Psychology, UHSR University, via Olgettina 58, I 20132 Milan, Italy; e-mail: lisa.scocchia@unimib.it)

In the flash-lag effect (FLE), observers see a flashed item colocalised with a moving item as lagging behind the moving item. In a previous study (Scocchia and Baud-Bovy, 2005 *Perception* 34 Supplement, 245), we investigated the effect of visuo-motor coupling in the FLE, and reported that the FLE is greater when the trajectory is controlled by the subject (motor condition) than when it is computer-generated (visual condition), suggesting an interaction between the motor and the visual systems. However, these findings could be explained by the greater attentive load implied by the double-task nature of the motor condition. To control for this possibility we added, to the paradigm used in the visual condition, two double-task conditions in which motor behaviour was not required. The concurrent task consisted of clicking the mouse when a distractor

appeared either at the fixation point or overlapping the moving dot. The attentive load required by the double task did not modulate the FLE, at least in this experimental paradigm. This result reinforces the hypothesis of a visuo-motor interaction and is in agreement with the motor theories of perception.

◆ **Awareness of one's own reaching movement: Integration of visual and motor signal**

J-P Orliaguet, F Boy¶, R Palluel-Germain¶, Y Coello§ (Laboratoire de Psychologie et Neuro-Cognition, UMR CNRS 5105, Université Pierre Mendès France, F 38040 Grenoble Cedex 9, France; e-mail: jean-pierre.orliaguet@upmf-grenoble.fr)

Using a video-controlled pointing task dissociating the motor and visual aspects of a movement, Boy et al (2005 *Neuroscience Letters* **386** 52–57) showed that visual information dominated when evaluating the spatial aspects of the movement and that kinesthetic/motor information was neglected. Following recent advances in the understanding of multisensory integration reported by Ernst and Bühlhoff in (2004), the goal of the present research is to show that weakening the accuracy of visual signals modifies the way one is aware of the spatial aspects of his/her own movements. Participants had to monitor 20 pointings from the real-time images provided by a camera placed above the workspace and displayed on a video-screen. A low-pass spatial filtering of the images reduced their spatial resolution. Direct vision of the workspace was precluded and rotating the camera generated a directional discrepancy between actual and viewed movement. Differently to Boy et al (2005), when images of movements are blurry, data showed that evaluations of the spatial aspects of action no longer rely on the exclusive processing of visual information but rather integrate kinesthetic and/or motor information. Thus, the integration of visuomotor signals in building movement perceptual awareness is a flexible and adaptive process that depends of the accuracy of the information afforded by visual signals.

◆ **Motion distance perception during active head movements**

S Ohtsuka, S Saida¶ (Department of Psychology, Saitama Institute of Technology, 1690 Husaiji, Okabe, Osato-gun, Saitama 369-0293, Japan; ¶ Department of Applied Physics, National Defense Academy, 1-10-20 Hashirimizu, Yokosuka, Kanagawa 239-8686, Japan; e-mail: satoko@sit.ac.jp)

We measured the perceived distance of moving targets yoked to observers' active head movements. The target moved in a uniform region in the same or opposite direction relative to lateral head movements. In a control condition, the observers viewed a target moving with constant speed without head movements. In experiment 1, the observers reported the distance only. Here we found no effect of head movements on distance perception. In experiment 2, the observers reported the positions of start- or end-points of motion as well as the distance. Here, the head movements had an effect on distance perception: This result could be explained by their influence on position perception. In experiment 3, the observers reported target velocity and duration as additional tasks. While head movements did not have an effect on distance perception, they did on the velocity and duration perceptions. The product of perceived velocity and duration is equivalent to the perceived distance. The results of these experiments indicate that active head movements affect to the perception of some aspects of a moving target. We also found a difference in the magnitude of distance perception in the three experiments. This could result from different strategies adopted in each experiment.

◆ **Effects of training of remote manipulation by a real hand on performance of tracking a virtual object with a virtual hand**

T Kawahara, T Yoshizawa, M Araki (Human Information System Laboratory, Kanazawa Institute of Technology, 3-1 Yatsukaho, Hakusan, Ishikawa 924-0838, Japan; e-mail: kawa@his.kanazawa-it.ac.jp)

Previous studies of hand movement in coordination with virtual-reality environment have shown that the spatial relation between positions of simulated hands in virtual-reality environment and of hands manipulating them in the real-world is an important factor in constructing a virtual-reality system providing a seamless environment between the system and its users. In such a system training to track virtual objects with a virtual hand can improve performance of remote manipulation with a real hand. To investigate the effects of the training, we measured the reaction time of a real hand manipulating a virtual hand for both dominant and non-dominant hands at ten spatial differences between the virtual and real hands when a tracking object reversed its direction of motion. For each experimental condition 200 trials were repeated, and we plotted the reaction time as a function of repetition of the trials. We found that a dominant hand was able to respond more remotely than a non-dominant hand with less reaction time. Moreover, a dominant hand could improve synchronicity with a virtual hand more quickly than a non-dominant hand.

[Supported by Japanese MEXT grant No.17560236 to TK.]

◆ **Cancellation of perceptual acceleration by galvanic vestibular stimulation with visually and physically rolled virtual environment**

T Maeda, J Watanabe¶, H Ando, M Takahashi§ (NTT Communication Science Laboratories, 3-1 Morinosato Wakamiya, Atsugi-shi, Kanagawa Pref. 243-0198, Japan; ¶also PRESTO Japan Science and Technology Agency; §Japan Advanced Institute of Science and Technology, Ishikawa 923-12, Japan; e-mail: maeda@avg.brl.ntt.co.jp)

As part of a process to identify potential simulator-sickness issues with virtual environments, we have conducted a study to address the experience of simulator sickness and presence under different displays of senses, visual, and physical motion, and galvanic vestibular stimulation (GVS). The virtual environment has three 80 inch × 60 inch screens. The two side screens are positioned at 120° angles to the central screen to give a three-sided display area that is 16 feet wide and approximately 7 feet deep. This allows for two different field-of-view (FOV) configurations: a one-screen setup that provides a 60° FOV, and a three-screen setup that provides a 180° FOV. Users are seated in front of the centre screen. The seat is a 3-DOF motion base, JoyChair-R1 (Kawada Industries, Inc.), rolling by servo driver synchronised to the virtual sight of computer graphics and GVS. Lastly, we were interested in determining whether or not the synchronised GVS would affect the experience of simulator sickness and presence. If GVS could cancel completely the physical acceleration driven by the motion base, the users would not be aware of the motion of the seat.

◆ **Visual selection is determined by action intention**

A Hannus, F W Cornelissen¶, H Bekkering§ (School of Behavioral and Cognitive Neurosciences, University Medical Center Groningen, NL 9700 RB Groningen, The Netherlands; Nijmegen Institute for Cognition and Information [NICI], Radboud University Nijmegen, Montessorilaan 3, NL 6525 HR Nijmegen, The Netherlands; Estonian Centre of Behavioural and Health Sciences, University of Tartu, Tiigi 78, EE 50410 Tartu, Estonia; ¶Laboratory for Experimental Ophthalmology, BCN Neuro-imaging Center, School of Behavioural and Cognitive Neurosciences, University Medical Center Groningen, University of Groningen, PO Box 30.001, NL 9700 RB Groningen, The Netherlands; §Nijmegen Institute for Cognition and Information [NICI], Radboud University Nijmegen, PO Box 9104, 6500 HE Nijmegen, The Netherlands; e-mail: aave.hannus@ut.ee)

The aim of this study was to investigate in more detail the influence of action intention on visual feature processing in a search task. Previous work has shown that processing of behaviourally relevant visual feature is enhanced by intention to execute a motor action. Here we tested if this effect results from a biased competition between the behaviourally relevant and the behaviourally neutral feature, or alternatively from an enhanced processing of the relevant feature per se. Subjects conducted both overt colour search (uniformly tilted coloured bars) and orientation search (uniformly coloured tilted bars) tasks and either grasped or pointed at the target while their eye movements were recorded. In the orientation search we found that in both pointing and grasping conditions target detection accuracy was approximately equal. However, in colour search, target discrimination performance was significantly lower in the grasping condition than in the pointing condition. We argue that in colour search, the intention to grasp the coloured bar increases the relevance of orientation of this bar in space and consequently discrimination performance on colour dimension decreases. The present study supports the idea of an action-induced biased competition between the visual features involved.

◆ **Motor expertise and the visual perception of biological motion**

A Casile, L Omlor, C L Roether, M A Giese (Laboratory for Action Representation and Learning, Department for Cognitive Neurology, Hertie Institute for Clinical Brain Research, University Clinic Tübingen, Schaffhausenstrasse 113, D 72072 Tübingen, Germany; e-mail: antonino.casile@uni-tuebingen.de)

Recent experimental evidence supports a link between the perception and execution of actions. Moreover, it has been proposed that the acquisition of a novel motor behaviour directly influences the visual perception of similar movements. We tested this hypothesis by using a novel training paradigm that effectively dissociates visual and motor learning. We assessed the recognition of novel gait patterns before and after a non-visual motor training. During training, subjects were blindfolded, receiving only verbal and haptic feedback. Moreover, at the end of motor training, subjects were motion captured while executing the novel coordination pattern. We found a selective improvement in the visual task for the trained movements. No improvement in the visual test was found for untrained motor patterns. Furthermore, after motor training, visual performance correlated significantly with motor performance, quantified from the motion capture data. These results are confirmed by a second study. We extracted emotion-specific spatiotemporal primitives

from kinematic data from human gaits using a novel unsupervised learning algorithm. We demonstrated that the emotion-specific features extracted from motor behaviour closely match the ones that are critical for the perception of emotions from gait.

[Supported by the Volkswagenstiftung, DFG (SFB 550), HSFP and Hermann Lilly Schilling Foundation.]

◆ **Social cues of attention mediate representational momentum**

M Hudson, T Jellema, C H Liu (Department of Psychology, University of Hull, Cottingham Road, Hull HU6 7SE, UK; e-mail: M.Hudson@2005.hull.ac.uk)

We report a new visual illusion in which the observer's judgment of the final position of a rotating head is determined by gaze direction. We employed a head which rotated from a left profile (-90°) toward the observer along the vertical axis, stopping at -30° . Gaze direction of the head was manipulated in three conditions: (i) eyes rotating faster than the head, stopping at 0° (looking toward the participant); (ii) eyes rotating at the same speed as the head (stopping at -30°); and (iii) eyes rotating slower than the head (stopping at -60°). We found that participants tended to overestimate the amount of head rotation when the eye gaze moved towards them beyond the final head position. Meanwhile, they tended to underestimate the rotation when the eye gaze was directed away from them. This finding may be attributed to an ecologically useful bias. Human movement may be anticipated to continue in the direction of attention, as signalled by gaze direction. Our data are consistent with the notion that gaze direction is automatically interpreted by the observer to attribute intentions.

ATTENTION, VISUAL SEARCH, CHANGE DETECTION, CHANGE BLINDNESS

◆ **Target-distractor similarity in visual search for line segments with specific curvature and orientation**

J Wagemans, E Verbeke¶, K Vliegen¶, G Kayaert, B Ons (Laboratory of Experimental Psychology [¶Department of Psychology], University of Leuven, Tiensestraat 102, B 3000 Leuven, Belgium; e-mail: johan.wagemans@psy.kuleuven.be)

We investigated the combined effect of two factors on visual search difficulty: the number of features shared between target and distractors and the parametric similarity between them. Our stimuli were simple line segments with specific curvature and orientation values, sampled from a 5×5 stimulus space. Triads of search trials were defined in which a target always differed from two distractors. Targets shared no single feature with the distractors (F0), or they shared one feature with one of the distractors but not the other (F1), or they had one feature value in common with one distractor and the other one with the second distractor (conjunction). Target–distractor similarity was manipulated in four steps and display size was 5, 10, or 15 search items. Targets were always present and participants had to indicate them by pointing with the computer mouse. The percentage of errors and reaction times increased monotonically with display size and target–distractor similarity, both for the number of features shared as well as parametrically. In addition, interesting asymmetries between the two dimensions of curvature and orientation, as well as in their interactions were found. We will relate these findings to perceived similarity as measured by independent ratings and same/different discrimination.

[Supported by IDO/02/004.]

◆ **Target frequency effect in visual search**

K Ishibashi, S Kita (Department of Psychology, Faculty of Letters, Kobe University, Rokkodai, Nada, Kobe 657-8501, Japan; e-mail: isibashi@lit.kobe-u.ac.jp)

A visual-search experiment was conducted to examine the frequency of target appearance as a factor affecting the reaction time required to detect a target among distractors. Unlike most experiments of visual search in which visual information or visual position are examined, we focused upon the frequency effect as a non-visual factor of visual search. In our experiments of visual search for the conjunctively defined target, we manipulated the frequency of target-present trials from 10% to 90%. Results showed that the observers showed longer reaction times in high-frequency conditions than in low-frequency conditions. This frequency effect was observed only in negative response trials (miss trials and correct rejection trials), but not in affirmative response trials (hit trials and false-alarm trials). This difference indicates that the frequency effect influences the reaction time in the decision to terminate the visual search. These results suggest that the frequency effect provides a new approach to the understanding of the process of visual search.

◆ **The mere exposure effect on attended and ignored stimuli**

Y Yagi, T Kikuchi (Graduate School of Comprehensive Human Sciences, University of Tsukuba, 1-1-1 Tennoudai, Tsukuba, Ibaraki 305-8572, Japan; e-mail: yyagi@human.tsukuba.ac.jp)

The mere exposure effect (MEE) refers to the phenomenon that previous exposures to stimuli increase participants' subsequent preference for those stimuli. We explored the effect of selective

attention on MEE. In the exposure phase, two nonsense line-drawings, red and green, were superimposed and presented at the centre of the display. Participants were asked to attend to one while ignoring the other (experiments 1 and 2), or to both (experiment 3). In the subsequent judgment phase, a pair of black line drawings, previously exposed and novel stimuli, appeared on both sides of fixation. Previously exposed stimuli were morphologically identical to red or green (ie, attended or ignored) drawings (experiment 1), or superimposed drawings (experiments 2 and 3) in the exposure phase. Participants were asked to make a two-alternative forced-choice judgment which stimulus they liked more. The results showed significant MEE only with attended drawings in experiment 1 and superimposed drawings in experiment 3, despite the fact that stimuli in the exposure phase were identical through all experiments. This indicates that MEE does not depend upon what participants are exposed to, but how participants process previously exposed stimuli.

◆ **Subitising made difficult: Effects of attentional set on visual enumeration**

P Vetter, B Butterworth, A Johnston¶ (Institute of Cognitive Neuroscience and Department of Psychology, University College London, 17 Queen Square, London WC1N 3AR, UK;

¶ Department of Psychology, University College London, Gower Street, London WC1E 6BT, UK; e-mail: p.vetter@ucl.ac.uk)

Visual enumeration has traditionally been hypothesised as two functionally separate processes, a fast and accurate subitising process for detecting 1–4 items and a slow and error-prone counting process for enumerating more than 5 items. Furthermore, subitising has been claimed to occur preattentively and in parallel, and counting to require serial attention. This experiment was aimed to test subitising performance while manipulating attentional set. Subjects were briefly presented with black and white dots randomly distributed on a grey background and were asked to enumerate either the white or the black subset. In the pre-cue condition, subjects were cued to the relevant subset before stimulus presentation and could selectively attend to the target subset and ignore the distractors. In the post-cue condition, however, subjects received the cue after stimulus presentation and could not allocate their attention to the relevant subset. It was hypothesised that if subitising occurs preattentively and in parallel, subjects should be equally accurate to subitise under both experimental conditions. However, enumeration accuracy was found to be significantly lower in the post-cue than in the pre-cue condition, both within and beyond the subitising range. This suggests that subitising is not independent from attentional set and therefore unlikely to occur preattentively.

[Supported by the European Marie Curie Research Training Network grant NUMBRA.]

◆ **Top-down inhibition for an irrelevant stimulus in attentional capture**

T Inukai, T Mori¶ (Graduate School of Psychology [¶ Department of Psychology], Chukyo University, 101-2 Yagoto-honmachi, Showa-ku, Nagoya 466-8666, Japan; e-mail: b10401d@cnc.chukyo-u.ac.jp)

Visual attention may be intentionally shifted to a particular location (top-down attentional control), and involuntarily captured by salient stimulus properties (bottom-up attentional control). The latter phenomenon is called attentional capture (eg Yantis and Jonides, 1984 *Journal of Experimental Psychology: Human Perception and Performance* **10** 601–621). Recent studies showed that these two kinds of controls have an influence on directing attention to a specific location and furthermore on processing of the properties at this location. In particular, Theeuwes et al [2000, in *Control of Cognitive Processes: Attention and Performance* volume VIII, Eds S Monsell, J Driver (Cambridge, MA: MIT Press) pp 105–124] reported that the top-down control allowed attention being captured by an irrelevant stimulus to inhibit processing of it so that the attention could be redirected to a more relevant stimulus as quickly as possible. In this context, we examined how attention could abandon involuntary processing. In experiment 1 we reconfirmed that only involuntary processing could produce attentional capture. In experiment 2 we found that the inhibition of processing lasted into the following stimulus. This suggests that the top-down control influences the processing not only of capturing stimulus but also of the following one, and so it inhibits the sequence of processing for a certain period.

◆ **Attending to the object defined with multiple primitive objects**

T Shimomura, T Mori¶ (Graduate School of Psychology [¶ Department of Psychology], Chukyo University, 101-2 Yagoto-Honmachi, Showa-ku, Nagoya 466-8666, Japan; e-mail: b10402d@cnc.chukyo-u.ac.jp)

When a part of an object is attended, a whole object can be processed efficiently as compared with other objects. This is called object-based attention, and suggests that visual attention can select an object as a set of information. Watson and Kramer (1999 *Perception & Psychophysics* **61** 31–49) showed that object-based attention would occur in the region that has uniform connectedness. Therefore, discontinuous properties, such as curvature and texture, could decide the object

boundary for allocation of attention. In addition to these bottom-up factors, they showed that a top-down factor, such as context, influences the boundary. However, since the object was ambiguous, it could be influenced by fewer top-down than bottom-up factors. In this study, using an object defined as an alphabet letter that has some different uniform connected regions, we investigated whether attention could select the object as a whole. We presented a letter consisting of rectangles and compared it with two parallel rectangles with regard to the effect of object-based attention. We found that these objects can be processed as a whole, despite the fact that they have curvature available for dividing them into parts. This suggests that attentional effect for an object would also depend on one's knowledge.

◆ **Perceptual rivalry in the complete absence of attention**

A Pastukhov, J Braun (Department of Cognitive Biology, Otto von Guericke University, Haus 1, Leipziger Strasse 44, D 39120 Magdeburg, Germany; e-mail: alexander.pastukhov@nat.uni-magdeburg.de)

To ascertain whether or not attention is required for perceptual alternations to occur, we engaged subjects' attention with an attention-demanding task in the centre of the visual field and presented a rivaling stimulus (moving plaid or rotating cylinder) in the periphery. For effective attention control, both central and peripheral stimuli were presented intermittently (400 ms on, 1000 ms off). After 10 consecutive presentations with both stimuli, there occurred 2 presentations with the peripheral (rivaling) stimulus only. When the central (attention-engaging) stimulus was present, observers reported on this stimulus and ignored the peripheral stimulus. As any lapse of attention would decrease central performance significantly, we are confident that the peripheral stimulus remained completely unattended during these trials. When the central stimulus was absent, observers reported the phenomenal appearance of the rivaling stimulus. The results showed that perceptual alternations continued even without attention (seven observers). However, absence of attention increased mean dominance times from 34 to 66 s, as reported previously for conditions of divided attention (Pastukhov and Braun, 2005 *Perception* 34 Supplement, 161). Our findings refute an attentional trigger for perceptual alternations, suggesting that rivalry is endogenous to the perceptual representation.

◆ **Focused attention in real three-dimensional space**

G Rinkenauer, M Grosjean (Institute for Occupational Physiology, University of Dortmund, Ardeystrasse 67, D 44139 Dortmund, Germany; e-mail: rinkenaue@ifado.de)

The influence of depth on focused visual attention was assessed within a real three-dimensional display. An Eriksen-flanker task was employed in which target and flankers were presented either at the same or at different depth planes. Each trial started with a binocular fixation cue that appeared either at the same or at a different depth plane as the subsequent target. As expected, reaction times were longer under incompatible than under compatible flanker conditions for all depth combinations. Moreover, responses were also faster when the cued and target planes were identical. However, the compatibility effects were larger when the target was presented at the near-depth than at the far-depth plane. This suggests an increase in the spatial attentional gradient with depth. It was also observed that the compatibility effect was modulated by the depth of the target only when the far depth plane was cued. This provides evidence that the depth of the target becomes irrelevant when it is beyond the cued depth, even though all stimuli were presented within Panum's area. Taken together, these findings point to the involvement of viewer-centred rather than object-centred attentional processes.

◆ **Quantitative prediction of errors in RSVP: Modeling the time course of suppression during the attentional blink**

E Vul, T Konkle, A Love, M A Williams, M Nieuwenstein (Department of Brain and Cognitive Sciences, Massachusetts Institute of Technology, 77 Massachusetts Avenue 46-4141, Cambridge, MA 02139, USA; e-mail: evul@mit.edu)

Selection of a target in a rapid serial visual presentation (RSVP) stream hinders processing of subsequent items—an effect referred to as the attentional blink (AB). Despite theories to the contrary, recent evidence suggests that the degree to which an item is blinked is a function of time elapsed between targets, rather than the serial position of the item. Wyble and Bowman [2004, in *Proceedings of the Sixth International Conference on Cognitive Modelling* Ed. C Schunn (Mahwa, NJ: Lawrence Erlbaum Associates)] reported lag-2 sparing in RSVP at 20 items s⁻¹. Furthermore, precuing targets during the attentional blink can substantially improve performance, suggesting that by triggering attention earlier, one can mitigate the AB (Nieuwenstein et al, 2005 *Journal of Experimental Psychology: Human Perception and Performance* 31 1463–1475). We propose a quantitative temporal model of the second stage of processing posited by Chun and Potter (1995

Journal of Experimental Psychology: Human Perception and Performance **21** 109–127) which accounts for both findings. This model is independently verified with a novel paradigm in which cues and targets are spatially and temporally separated. This method, coupled with analyses of intrusions around the second target, affords a precise measure of the speed of attentional selection at different intervals from the preceding target. Further, this paradigm allows us to manipulate cue onset independently of target onset; thus dissociating the two stages of processing. Our results are best accounted for by a mechanisms of continuous suppression rather than a processing bottleneck.

◆ **Location effects on attentional capture**

M I García-Ogueta (Department of Basic Psychology, Psychobiology and Methodology, Universidad de Salamanca, Avenida de la Merced 109-131, E 37005 Salamanca, Spain; e-mail: ogueta@usal.es)

Transient luminance changes, even non-predictive of relevant stimuli, cause attentional capture to the location where the change occurs. According to Corbetta and Shulman (2002 *Nature Reviews Neuroscience* **3** 201–215) this exogenous mechanism, proposed to detect behaviourally relevant stimuli, is a ventral system strongly lateralised to the right hemisphere. If this were so, could we expect differential location effects on attentional capture? The object of this research is to find out whether the incongruent transient captures attention independently of being ipsilateral or contralateral to the stimulus and, also, whether the strength of capture differs with locations. Pre-cued voluntary orienting overcomes attentional capture by a transient change. The question is whether this modulation of capture occurs similarly in all locations. Results show that the incongruent transient captures attention, increasing RT and decreasing stimulus processing accuracy. The disruptive effect is the same in an ipsilateral and a contralateral location. The only differential location effect is a larger disruption in accuracy with an incongruent capture in the upper location of vertical meridian. Voluntary orienting of attention overcomes the incongruity to the same extent in all locations. Effects of incongruent capture are not related to response priming (transient-response compatibility). Results should also be considered in relation to ocular factors.

◆ **Capacity limits for the detection of changing visual features**

A Burmester, G M Wallis (School of Human Movement Studies, University of Queensland, Brisbane, QLD 4072, Australia; e-mail: aburmester@hms.uq.edu.au)

Capacity limits in visual attention have traditionally been studied with static arrays of elements from which an observer must detect a target defined by a certain visual feature or combination of features. Here, we used a visual-search paradigm, with accuracy as the dependent variable, to examine capacity limits for different visual features undergoing change over time. Stimuli used in these experiments were Gabor gratings placed in a circular ring around a central fixation point. In experiment 1, detectability of a single changing target was measured under conditions where the type of change (size, speed, colour), the magnitude of change, the set size, and distractor homogeneity were all systematically varied. Psychometric function slopes were calculated for different experimental conditions and 'change thresholds' extracted from these slopes were used in experiment 2, in which two suprathreshold changes were made simultaneously, in each trial either to the one object or across two objects (ie a single change for each object). Comparisons were made between changes in different features, and the interactive effects of multiple changes (across multiple feature dimensions and objects) were examined.

◆ **Attentional mechanisms modulate the evolution of IT cortical activity during object perception**

C Bordier, J Prado[¶], K Knoblauch (Inserm U371, Cerveau et Vision, Department of Cognitive Neuroscience, 18 avenue du Doyen Lepine, F 69500 Bron, France; [¶] Institut des Sciences Cognitives, CNRS, UMR 5015, Raisonnement Développement et Pragmatique, 67 boulevard Pinel, F 69675 Bron Cedex, France; e-mail: bordier@lyon.inserm.fr)

Several studies demonstrate attentional mechanisms modulating ventral visual pathway activity. While both bias and gain mechanisms have been proposed, their individual roles during object perception remain largely unknown. We investigated the influence of attention on cerebral activity related to the perception of objects that were gradually revealed, allowing us to measure the evolution of recognition. During fMRI scans (1.5 T), eighteen observers were presented with two types of visual stimulus series (11 deg × 11 deg), images of objects in context or pink (1/f) noise, and an auditory stimulus, one of three pure tones. Each series consisted of a sequence of ten low-pass (Gaussian) filtered images (0.5 s duration, 4.5 s ISI), with bandwidth increasing in half-octave steps. Subjects underwent two sessions. In the first, they performed a difficult auditory discrimination task while fixating the images; in the second, an image recognition task. In the infero-temporal cortex, the response to objects displayed a greater activity than noise only during the visual recognition task. This differential activity showed increasing modulation

with increasing image bandwidth until object recognition. Furthermore, an attention-dependent increase in activity occurred even for pink noise. These results suggest that both baseline and gain modulation mechanisms influence the process of object perception.
[Supported by Emergence 2005, Région Rhône-Alpes.]

◆ **Visual search of objects with different orientation**

V N Chihman, V M Bondarko (Department of Information Technology, Pavlov Institute of Physiology, Russian Academy of Sciences, nab. Makarova 6, 199034 St Petersburg, Russia; e-mail: niv@pavlov.infran.ru)

In a set of automated psychophysical experiments we studied dependences of detection of objects having different orientation on the number of distractors and separation between them. Two types of synthesised images were used: lines of 20 or 40 min of arc length and rings of equal diameters with a segment deleted. The images were organised as a 2-D array consisting of 3×3 to 8×8 elements. The orientation of the distracting lines was 45° and that of the target line was 135° . The orientation of the distracting incomplete rings differed from that of the target rings also by 90° . Background masking was used. Observers' task was to indicate a presence or absence of the target with 'yes' or 'no'. The software was developed for real-time experiments and run on an IBM PC compatible computer. We found detection deterioration with increasing separation, but the dependences on the number of distractors differed between the lines and the fragmented rings. Detection was better in arrays of 4×4 or 5×5 elements for lines, but for incomplete rings it gradually deteriorated with increasing number of distractors in the array. We discuss the mechanisms of preattentive discrimination and visual search as possible causes.
[Supported by RFBR grant 06-07-89137-a and RFH grant 06-06-00252a.]

◆ **Feature type modulates priming in visual search**

J McBride, I D Gilchrist, U Leonards (Department of Experimental Psychology, University of Bristol, 12A Priory Road, Bristol BS8 1TU, UK; e-mail: jen.mcbride@bristol.ac.uk)

When target features are repeated across consecutive search trials, response times (RTs) are faster compared to trials in which target features change (eg Maljkovic and Nakayama, 1994 *Memory & Cognition* **22** 657–672). To investigate how feature type and the roles that features play in target definition affect priming, we manipulated the roles of colour and orientation in defining the search target, while participants responded to the orientation of a 'T' inside this target. In experiment 1, the target differed from distractors in orientation, while target colour was irrelevant to the search. Repeating irrelevant target colour produced significantly faster RTs, but repeating target-relevant orientation slowed RTs. In experiment 2, the roles of colour and orientation were reversed: the target now differed from distractors by its colour, while target orientation was irrelevant. Again, a significant RT advantage was found for repeating target colour, but not for repeating target orientation. Thus, it seems that repetition priming is at least partly dependent on feature type, rather than the role of feature type in target definition. Furthermore, these data are not consistent with suggestions that an episodic representation of the target (Huang et al, 2004 *Memory & Cognition* **32** 12–20) is stored across trials.
[Supported by a BBSRC postgraduate studentship.]

◆ **Priming visual search by detected and undetected changes**

A Renner¶, A Maiche, I G Sligte§ (Departament de Psicologia Bàsica, Evolutiva i de l'Educació, Laboratori de Percepció i Psicofísica, Universitat Autònoma de Barcelona, E 08193 Bellaterra, Spain [¶] also Department of Psychology, University of Amsterdam, Roetersstraat 15, NL 1018 WB Amsterdam, The Netherlands]; §Department of Psychology, University of Amsterdam, Roetersstraat 15, NL 1018 WB Amsterdam, The Netherlands; e-mail: Anna.Renner@yahoo.com.mx)

Even though we can only attend to a few objects at the same time, we have the impression that our visual experience is complete. The change blindness (CB) phenomenon reveals that this subjective impression is mistaken. Despite broad consensus that focused attention is necessary to (explicitly) detect changes, well-known phenomena such as blindsight, eg reported by Weiskrantz in 1986, imply the possibility of implicit visual processing. In the present experiment, we addressed this idea by investigating priming effects of detected (explicit) and undetected (ie implicitly detected) changes in a CB paradigm on a subsequent visual-search task (VST). Since the target of the VST always appeared at the same location as where the previous change occurred, we expected explicitly detected changes to facilitate target detection. Results show that reaction times (RTs) in the VST after explicitly detected changes were significantly faster than when no change had occurred. However, RTs after implicitly detected changes were significantly slower. These results seem to suggest that explicit change detection is 'focusing' attentional mechanisms to specific spatial locations, while implicit change detection may produce a reverse effect.

◆ **The role of endogenous orienting in change detection: Does attentional processing differ in the one-shot and flicker paradigms?**

P M Pearson, E G Schaefer, M Schellenberg, J M McLachlan (Department of Psychology, University of Winnipeg, 515 Portage Avenue, Winnipeg, MB R3B 2E9, Canada; e-mail: p.pearson@uwinnipeg.ca)

Younger and older participants completed a change-detection task with an identical set of driving scenes. Observers in the one-shot paradigm were shown each of the images in a pair for 15 s each only once, and accuracy of identification of alterations was assessed. In the flicker paradigm, the two images in a pair were alternated rapidly for up to 1 s and the time to correctly identify alterations was measured. In both paradigms, alterations to items of central interest were detected better than those to items of marginal interest. Although disappearances were identified better than positional changes in the one-shot paradigm, type of change had no effect in the flicker paradigm. Similarly, in the one-shot paradigm, alterations relevant to the gist of the scene were detected better than irrelevant alterations, whereas relevance had no effect on performance in the flicker paradigm. This pattern of results was obtained for both younger and older observers. These findings indicate that the role of endogenous processing is minimised in the flicker paradigm relative to that in the one-shot paradigm and are consistent with the suggestion that change-detection in the one-shot paradigm may be verbally mediated.

[Supported by UW-CIHR and NSERC Discovery Grant to PMP]

◆ **Role of eye movement and attention on temporary blindness and target reappearance**

L-C Hsu, S-L Yeh¶, D-L Tang§ (Medical College of the China Medical University, 91 Hsueh-Shih Road, Taichung 40402, Taiwan; ¶ Department of Psychology, National Taiwan University, Roosevelt Road, Taipei 106, Taiwan; § Department of Mass Communication, Chinese Culture University, 55 Hwa-Kang Road, Yang-Ming-Shan, Taipei 11114, Taiwan; e-mail: lchsu@mail.cmu.edu.tw)

Motion-induced blindness (MIB) and perceptual filling-in (PFI) are two phenomena of temporary blindness in which, after prolonged viewing, perceptually salient targets repeatedly disappear out of view for several seconds. Previous studies of PFI emphasise the importance of retinal adaptation to the target boundary and suggest that eye fixation is necessary for target disappearance and eye movement leads to target reappearance. We have shown that MIB and PFI share common mechanisms, and that, although boundary adaptation is involved in MIB and PFI, it is neither a necessary nor a sufficient condition (Hsu et al, 2006 *Vision Research* 46 1973–1981). This raises the doubt whether eye fixation/movement is necessary for target fading/reappearance. We hypothesise that target fading is caused by competition between target and background elements for visual awareness, through the attention mechanism. To test this, we monitored eye movement and manipulated attention in both MIB and PFI. Although participants reported more fading when their eyes fixated than when they moved, they still experienced target reappearance with strict eye fixation. In contrast, attention manipulation without eye movement affected target fading and reappearance, supporting the view that attention is critical for the temporary blindness in MIB and PFI.

[Supported by NSC94-2752-H-002-008-PAE and NSC95-2413-H-039-002.]

◆ **How the type of cueing interacts with image properties in visual short-term memory storage**

E Gavault, A Israel, T Ripoll (Laboratoire de Psychologie Cognitive, CNRS UMR 6146, Université de Provence–Centre St Charles, Bâtiment 9, Case D, 3 place Victor Hugo, F 13331 Marseille Cedex 3, France; e-mail: gavault@up.univ-aix.fr)

Recent experiments showed that attention-directing cues influence the transfer of perceptual information into visual short-term memory (VSTM). The purpose of our study was to specify the functional links between attentional mechanisms and the encoding of information in VSTM. We used an original paradigm in which participants had to memorise the shapes and the locations of four targets presented among four distractors. To cue the targets, the participants of three experimental groups previewed either distractors, distractor locations, or target locations. The participants of these experimental groups showed better performance than the participants of a control group who only saw targets among distractors. These results suggest that endogenous attention can select multiple targets among distractors in order to store them in VSTM. These mechanisms of selection and transfer to VSTM, however, seem to differ according to the type of cueing. Indeed, performances deteriorated when the target locations were cued beforehand if one distractor in the memory array made a pop-out (its colour differed from the others). Participants who previewed the distractors or their locations were not sensitive to this popout. These results have implications for further understanding links between attention and VSTM in term of inhibition.

◆ **The role of attention in change detection task**

F Taya, K Mogi (Sony Computer Science Laboratories, Inc., Takanawa Muse Building 3-14-13, Higashigotanda, Shinagawa-ku, Tokyo 141-0022, Japan; e-mail: taya@csl.sony.co.jp)

Change blindness is an interesting phenomenon where subjects fail to detect even a large change in the visual scene. It has been suggested that focused attention is necessary for the detection of a change, but it is not sufficient. The reason why such a change fails to be registered remains to be clarified. One possibility is that the preserved representation is sparse so that the detailed information necessary for detecting the change is lacking. Another possibility is that the change is detected unconsciously but fails to be consciously perceived. It has also been said that semantic information is used in the comparison process. Here, we recorded eye movements while the subjects were looking at flicker images. By conducting a series of statistical analyses on the eye-tracking data, we investigated the relationship between the eye positions and the positions of detected changes, clarifying which aspects of the stimuli are crucial in change detection. The visual memory task was also conducted before the change detection task in order to study the effect of the representation stored in the memory on the degree of change blindness. On the basis of the results we discuss the role of attention and semantic representation in change blindness.

◆ **Attention improves the perception of speed but not direction changes in transparent motion**

V Kozyrev, S Ardid¶, D Luxat§, A Lochte, S Treue (Laboratory of Cognitive Neuroscience, German Primate Center, Kellnerweg 4, D 37077 Göttingen, Germany; ¶ Instituto de Neurociencias, Universidad Miguel Hernandez-CSIC, E 03550 Sant Joan d'Alacant, Spain; § Center for Complex Systems, Brandeis University, Waltham, MA 02454, USA; e-mail: vkozyrev@dpz.gwdg.de)

The perception of individual directions in transparent motion (stimuli that combine two or more directions within the same spatial area) is a difficult task for the visual system. To elucidate the underlying mechanisms, we compared the perception of speed and direction of motion: human observers had to respond to brief changes of either direction or speed in eccentrically presented moving random dot patterns. Unidirectional and transparent bidirectional (directions 90° apart) stimuli were used, and in the transparent conditions subjects were either instructed which direction would change (cued transparent condition) or this information was not provided (uncued transparent condition). Thresholds in the speed task were similar in the unidirectional and cued transparent conditions. This was not the case in the direction tasks: here, thresholds were similar in the two transparent conditions and about twice as high as in the unidirectional condition. These data show that the allocation of attention to one of the directions in transparent motion helps to remove the noise introduced by the other direction in speed but not in direction judgments. Therefore it is likely that speed and direction processing is based on mechanisms that differ if and how they benefit from attention.

[Supported by the Volkswagen Foundation, grant I/79868.]

◆ **Movement neurons in the frontal eye field is not activated by covert shifts of both exogenous and endogenous attention**

A Ignashchenkova, T Haarmeier¶, P Thier (Department of Cognitive Neurology, Hertie Institute for Clinical Brain Research, University of Tübingen, Otfried-Mueller Strasse 27, D 72076 Tübingen, Germany; ¶ Department of General Neurology, University Clinic of Tübingen, Hoppe-Seyler Strasse 3, D 72076 Tübingen, Germany; e-mail: alla@uni-tuebingen.de)

The 'motor theory of attention' holds that overt shifts of attention (saccades) and covert shifts of attention share a common substrate. With this theory in mind, we asked if the same frontal-eye-field (FEF) neurons, activated by saccades, are also activated by covert shifts of attention. Monkeys were trained on two paradigms requiring exogenous and endogenous attentional shifts, respectively, by cueing a discriminandum either spatially precise or symbolically (an arrow-like object presented at the fixation point). We tested neurons with a motor response preceding saccade execution ('movement neuron') with the discriminandum and the spatially precise cue placed in the motor field of a given cell. We did not observe any specific discharge components in movement neurons in the period between the presentation of the cue and the discriminandum, in which the covert shifts of attention would be expected to take place. These observations suggest that the role of movement neurons of the FEF is restricted to the generation of overt shifts of attention and the involvement of FEF in covert shifts proposed by electrical microstimulation studies should be explained by a specific activation of other types of neurons such as visuo- or/and visuomotor cells.

◆ Visual search of the second order stimuli

M A Bozhinskaya, V V Babenko (Department of Psychology, Rostov State University, Nagibin av. 13, 344038 Rostov-on-Don, Russia; e-mail: bvv@psyf.rsu.ru)

To explain the ability to detect modulations of contrast, orientation, and spatial frequency 'filtering – nonlinearity – filtering' models are suggested. It is assumed that all stages of the models are preattentive. But in the case of second-order mechanisms (SOM) this is not obvious. The aim of our research was to determine the nature of mechanisms providing the detection of orientation or spatial-frequency modulation in a visual-search task. The search was effective when the target had modulated orientation and the distractors were unmodulated. The search became slower when the target and the distractors changed places. The results demonstrate the preattentivity of SOMs which detect the modulation of orientation. The search was also effective when the target had the modulated spatial frequency and the distractors were unmodulated. But it still remained effective in the reversed situation. This proves that the detection of spatial-frequency modulation is preattentive. But an absence of search asymmetry may indicate the presence of SOM selective both to unmodulated and modulated patterns throughout the spatial frequency. Thus the preattentivity is general for these mechanisms. However, from the obtained results we cannot conclude if the SOMs are stable or programmed from above, depending on the task.

◆ Attention-induced motion blindness and the effect of distractor inhibition

M Milders, J L Hay, A Sahraie¶, M Niedeggen§ (School of Psychology [¶] Vision Research Laboratories], University of Aberdeen, Aberdeen AB24 2UB, Scotland, UK; § Institute of Experimental Psychology, Heinrich Heine University, Universitätstrasse 1, D 40225 Düsseldorf, Germany; e-mail: m.milders@abdn.ac.uk)

Impaired detection of motion targets can be induced in normal observers. We used a task consisting of two simultaneous rapid serial visual presentation streams. A local stream consisted of a fixation point rapidly changing colour and was surrounded by a global stream consisting of random-dot patterns moving in random directions or coherently in the same direction in 100 ms episodes. The target was coherent motion occurring simultaneously with, or shortly after onset of, a cue in the local stream (eg red fixation). Impaired motion-target detection occurred when coherent motion distractors appeared prior to the cue, which led us to propose that the effect results from carryover of inhibition of these distractors. This proposal is in line with visual-marking studies which showed that carryover of distractor inhibition can impair the ability of singletons to capture attention. In the current study we further increased the impairment in motion perception by making the cue more difficult to detect. These results were not caused by the extra time required to detect the cue and support the hypothesis that distractor inhibition is responsible for the motion-blindness effect. Distractor inhibition would increase when cue detection is more demanding in order to improve selection efficiency.

◆ Interaction of reflexive and volitional orienting

B Olk (International University Bremen, School of Humanities and Social Sciences, PO Box 750561, D 28725 Bremen, Germany; e-mail: b.olk@iu-bremen.de)

Attention improves the detection of visual targets and can be engaged with or without the intention to attend to a specific stimulus. Recent research (Ristic and Kingstone, in press; Olk, Cameron, and Kingstone, submitted) has indicated that cues, such as central arrows, that were long believed to elicit volitional orienting, trigger also reflexive attention. Moreover, when such cues are highly predictive (80%) of target location, the resulting attention effect will be greater than the sum of reflexive and volitional orienting. To characterise the interaction of reflexive and volitional orienting in response to arrow cues, I investigated how reliable predictive cues have to be in order for the enhanced attention effect to occur. Cue predictability was increased systematically (50%, 60%, 70%, or 80% predictive) and the effects of central arrow and central number cues were compared. For central numbers, cues had to be highly predictive for cueing effects to occur; indicating that orienting to these cues was volitional in nature. For central arrows, cueing effects emerged at all predictability levels and increased gradually with increasing predictability. Importantly, cueing effects obtained for arrows (also when corrected for their reflexive component) exceeded those of central numbers, showing the enhanced attention effect.

◆ Exogenous attention reduces the effect of contrast adaptation by increasing contrast sensitivity

F Pestilli, J Viera, M Carrasco¶ (Department of Psychology [¶] and Center for Neural Science], New York University, 6 Washington Place, New York, NY 10003, USA; e-mail: franco@nyu.edu)

Contrast adaptation changes contrast sensitivity by resetting it to the local history of stimulation (the adapter contrast) effectively optimising sensitivity to the current stimulation. Transient attention

automatically enhances contrast sensitivity at valid-cue locations and impairs it at invalid-cue locations. We investigated how transient attention increases contrast sensitivity after contrast adaptation. We assessed accuracy in an orientation-discrimination task for Gabors, whose contrast ranged from 1%–100%. Observers adapted to Gabors with either 100% or 0% contrast (counterphase modulated) along the horizontal meridian. An uninformative precue directed transient attention to one of the two Gabors. A response cue defined the target Gabor. On valid-cue (invalid-cue) trials the response-cue pointed to the precued (the other) Gabor. On neutral-cue trials the precue appeared at fixation and the response cue indicated either stimulus with equal probability. Contrast adaptation decreased sensitivity in the three cue conditions. Transient attention increased contrast sensitivity at valid-cue locations and decreased it at invalid-cue locations to a similar degree in both adaptation conditions. Attention counteracted contrast adaptation: sensitivity for the adapted stimulus following a valid-cue was similar to that for the non-adapted stimulus following a neutral-cue. This suggests that automatic transient attention can reduce the effect of contrast adaptation.

◆ **Eriksen's flanker task: Continuous variation in perceptual load reveals independent contributions of flanker compatibility and flanker load**

I M Verstijnen, B Hekking (Department of Psychology: Experimental Psychology, Faculty of Social and Behavioural Sciences, University of Utrecht, Heidelberglaan 2, NL 3584 CS Utrecht, The Netherlands; e-mail: i.m.verstijnen@fss.uu.nl)

Lavie's (1995 *Journal of Experimental Psychology: General* **133** 229–354) perceptual load theory maintains that the extent of the flanker compatibility effect (FCE) depends on the perceptual load of the target. Excess perceptual resources will be automatically directed to the flankers. This implies that the perceptual load of the flankers may then start to influence behaviour. We investigated how flanker load and flanker compatibility contribute. Stimuli consisted of targets and flankers from 4 series of figures (Verstijnen and Wagemans, 2004 *Perception* **33** 531–546). Each series ranged from an unambiguous extreme (eg duck) via ambiguous intermediates (duck/rabbit) to another unambiguous extreme (rabbit). It was assumed that perceptual load coincided with ambiguity. Also by assigning different response buttons to each extreme of a series, a FCE effect should be found. In experiment 1 both target and flankers were shown for 150 ms. An increase in target load and flanker load indeed slowed down reaction times as did flanker incompatibility, the first at the expense of the latter two. Moreover, experiment 2 showed that masking the flankers after 14, 42, or 70 ms reduced the FCE effect (Schwarz and Mecklinger, 1995 *Perception & Psychophysics* **57** 1045–1052), but masking did not affect the effect of target load, and interestingly so, not of flanker load either. Altogether, these experiments suggest that flanker load and flanker compatibility are independent contributors.

◆ **Change blindness: Effects of changing the location of change**

M L T Vergeer, J C M von Schmid, R van Lier (Nijmegen Institute for Cognition and Information [NICI], Radboud University Nijmegen, PO Box 9104, NL 6500 HE Nijmegen, The Netherlands; e-mail: m.vergeer@nici.ru.nl)

To study the role of the location of change in change blindness we investigated performance differences in a detection task in which the location of change could be varied within a single trial. In a random pattern of 15 red and 15 green small disks, colour changes (red to green or green to red) occurred repetitively at the same location (alternation condition) or at different locations on each frame. In the latter case, either the colour of a randomly chosen disk (random condition), or of the disk closest to the location of the last change (snake condition) was changed on each consecutive frame. In all conditions, the within-trial ratio of red to green disks was kept the same. The participants had to respond when a change was seen and, subsequently, indicate where the change occurred. The results show that change detection was fastest in the alternation condition, intermediate in the random condition, and, remarkably, slowest in the snake condition. We discuss these findings in terms of different underlying mechanisms in change detection.

[Supported by an NWO grant to MV.]

◆ **Attentional control over either of the two competing percepts for the Necker cube**

R van Ee, J W Brascamp, A J Noest¶, A V van den Berg§ (Helmholtz Institute, Utrecht University, Princetonplein 5, NL 3584 CC Utrecht, The Netherlands; ¶ Department of Functional Neurobiology, Utrecht University, Padualaan 8, NL 3584 CH Utrecht, The Netherlands; § Department of Biology and Helmholtz Institute, Hugo R Kruijtbouw, Padualaan 8, NL 3584 CH Utrecht, The Netherlands; e-mail: r.vanee@phys.uu.nl)

The instruction “hold a percept” in bistable perception commonly encourages subjects to increase the percept durations for the ‘held’ percept but also to decrease the durations for the complementary ‘non-held’ percept. An interesting question is whether the subjects decrease the duration of the

non-held percept because there exists a genuine limitation on the control of a single percept, ie only pair-wise modification is possible. For the Necker cube, we employed specific variations in voluntary control instructions over either of the two competing percepts. Gaze recordings demonstrated that there were no systematic differences in fixation location during either of the two percepts across the various voluntary control conditions. We analysed the two parameters of the gamma fit to the percept reversal rate distribution. Such an analysis involves two dimensions of data variation, rather than the conventionally used mean rate, facilitating our conclusion that observers do have quite independent control over the (distribution of) reversals of either of the two percepts, at least for the Necker cube.

[Supported by the Netherlands Organisation for Scientific Research.]

◆ Visual search with and without target object recognition

L Zhaoing (Department of Psychology, University College London, Gower Street, London WC1E 6BT, UK; e-mail: z.li@ucl.ac.uk)

The search stimulus had 30×22 objects, each made of two intersecting bars. The target object had a uniquely oriented bar, making it moderately salient but not enough to attract the first saccade in most trials. At a seemingly random time T_{mask} after stimulus onset, identical masks replaced all target/distractors without perceptible afterimages. We measured reaction time RT_{eye} when the gaze first arrived at target location. When the target was a rotated version of all distractors, its localisation, reported by button presses, worsened with longer target viewing time $T = T_{\text{mask}} - RT_{\text{eye}}$ up to 1–2 s. This suggests that rotationally invariant target object recognition interfered with the task requiring only bottom-up orientation feature search (Zhaoing and Guyader, 2005, work presented at the Society for Neuroscience Annual Meeting, No.642.16). When mask onset occurred without gaze having arrived at the target, the gaze ultimately arrived at the masked target location with 15% probability, often after more than one post-mask saccade, before subjects' forced-choice button press. Target localisation in these post-mask arrival trials was significantly better than in non-arrival trials, for negative T down to -1 s, manifesting bottom-up salience from pre-mask stimuli in 'blind' searches. The button response latency after RT_{eye} was shorter for trials with shorter or negative T .

[Supported by Gatsby Charitable Foundation.]

◆ Top-down modulation in inefficient search: Evidence of differences between orientation and colour cuing

G M Anderson, D Heinke, G W Humphreys (School of Psychology, University of Birmingham, Edgbaston, Birmingham B15 2TT, UK; e-mail: gma472@bham.ac.uk)

We examined the effects of pre-trial cuing of the target on conjunction visual search. In all experiments, two targets were used: either a blue horizontal or a green vertical bar, amongst blue vertical and green horizontal bar distractors. The cue stimulus was either informative (predicting target colour or orientation) or non-informative. For experiment 1, array size was either 7 or 15, with a 50 : 50 distractor ratio. Valid cuing led to a decrease in reaction time and increased search efficiency, while invalid cuing had opposite effects. Colour cuing led to a larger modulation of RT compared to orientation cuing, but cue dimension had no effect on search efficiency. In experiment 2, distractor ratio was varied while array size was constant. The cue validity effect varied with distractor ratio (stronger cuing to the smaller group), but dimensional modulation was additive across different ratios. The results suggest that cue validity affects processes at a perceptive level, guiding search to a cued subset of stimuli. However, the dimensional differences in attention modulation suggest either an early advantage for colour in segmenting the display into relevant and irrelevant regions, or that the colour cue allows faster translation of target detection into a response.

◆ Interaction between facilitation and inhibition of return facilitates visual search

G Campana, C Casco (Dipartimento di Psicologia Generale, University of Padua, via Venezia 8, I 35131 Padua, Italy; e-mail: gianluca.campana@unipd.it)

It has been suggested (Pratt and Castel, 2001 *Vision Research* 41 3903–3908) that either inhibition of return (IOR) or facilitation of return (FOR) occurs in discrimination tasks, depending on some arbitrary combination of target features and task demands. Here we show that: (a) FOR always occurs to the non-responding feature or location; (b) FOR is always coupled to the responding feature whereas IOR is always coupled to the responding location; (c) there is an interaction between the effects associated with responding and non-responding features/locations (either FOR–FOR or IOR–FOR). Overall, these results support the distinction between two separate visual functions which interact resulting in an ecologically plausible heuristic that facilitates recently viewed features which have appeared in recently visited locations and inhibits recently visited locations that contain features recently associated with a distractor.

-
- ◆ **Simultaneous but independent priming of different features of a single object in visual search**
Á Kristjánsson (Department of Psychology, University of Iceland, Reykjavik, Iceland;
e-mail: ak@hi.is)

Many examples indicate that recent viewing history has a large effect upon visual-search performance (Kristjánsson et al, 2002 *Cognition* **85** 37–52; Kristjánsson, 2006 *Visual Cognition* **13** 324–362). It remains unclear, however, whether different features of an object show independent but simultaneous priming. Observers searched for a three-featured object (a Gabor patch that was either red-scale or green-scale, oriented to the left or right of vertical, and of high or low spatial frequency) among distractor Gabors with different values along these feature dimensions. The target-defining feature, the response-defining feature, and the irrelevant feature, were varied between different experiments. Task-relevant features (target-defining, or response-defining) always resulted in priming, while task-irrelevant features did not, except that colour always primed, even when task-irrelevant. Further experiments showed that priming from task-irrelevant spatial frequency and orientation could only occur when the other feature of the two was kept constant across all display items, perhaps reflecting that homogeneity of distractor sets allows faster rejection of array items as nontargets, so that less effort is required for the analysis of those items. Priming of individual features argues against views that priming operates on whole objects rather than individual features.

[Supported by Human Frontiers Science Program, University of Iceland; MRC, England.]

THURSDAY
ORAL PRESENTATIONS**EVOLUTION OF VISION**◆ **Vision and the organisation of behaviour**

J Zeil, J M Hemmi, N Boeddeker (ARC Centre of Excellence in Vision Science, and Centre for Visual Sciences, Research School of Biological Sciences, Australian National University, PO Box 475, Biology Place, Canberra, ACT 2601, Australia; e-mail: jochen.zeil@anu.edu.au)

Vision operates in a closed-loop. Behaviour constantly influences the distribution and pattern of light on the retina. Eye and body movements of animals are often organised to either facilitate extraction of visual information—for instance by separating the effects of rotation and translation in the optic flow field—or to generate specific visual information—as in the case of motion-based distance cues. We review examples of how the organization of behaviour is driven by the needs of visual information processing in the context of flight control (Boeddeker et al, 2005 *Journal of Comparative Physiology A* **191** 1143–1155), view-based homing (Voss and Zeil, 1998 *Journal of Comparative Physiology A* **182** 377–387), and predator avoidance (Hemmi and Zeil, 2005 *Marine Ecology Progress Series* **287** 274–278); examples serving as reminders of the interdependence of visual processing and behavioural organisation.

◆ **Trade-offs between information processing and energy consumption in the evolution of insect photoreceptors**

J E Niven (Smithsonian Tropical Research Institute, Roosevelt Avenue, Tupper Building–401, Balboa, Ancón, Panamá, República de Panamá; e-mail: nivenj@si.org)

Visual processing is constrained by relationships between energy consumption and signal quality. Animals have a limited energy budget to expend on neural processing but they must also extract reliable information from their environment to generate adaptive behaviour. During the evolution of the visual system the interplay between these factors is likely to have influenced the numbers and types of ion channels and transduction units in neurons, as well as their size. Comparative studies of insect photoreceptors allow the potential role of these trade-offs in the evolution of the visual system to be analysed by using empirical data. We determined the relationships between energy consumption and performance in homologous R1-6 photoreceptors from four species of fly: *Sarcophaga canaria*, *Calliphora vicina*, *Drosophila melanogaster*, and *D. virilis*. These relationships emphasise the importance of both the maintenance and signaling costs, which grow out of proportion to performance, resulting in a law of diminishing returns that penalises excess capacity. Comparison of chromatic and achromatic photoreceptors in *C. vicina* and *D. virilis* emphasises the fine tuning of these relationships even within the same eye. It is suggested that these relationships apply not just to the visual system but to all neurons, because they are subject to similar biophysical constraints.

[Supported by BBSRC, Smithsonian Tropical Research Institute.]

◆ **Depth perception during stationary flight in Spingids: behaviour, neurons, and a model**

M Wicklein (Department of Visual Science, University College London, 11–43 Bath Street, London EC1V 9EL, UK; e-mail: m.wicklein@ucl.ac.uk)

Spingids fly fast, are highly maneuverable and feed while hovering in front of flowers, and are therefore an excellent model to study visual detection of change in distance. Moths approach flowers fast, decelerate, and then stop in front of the flower to feed. They stay airborne throughout their feeding bout and hover, maintaining exact position in front of the flower, even if it moves, irrespective of movement direction through visual cues. Intracellular recordings in *M. sexta* and *M. stellatarum* have identified several physiologically and anatomically distinct classes of wide-field neurons that respond to looming or receding stimuli. Two very different strategies for detection of distance are realised in these neurons. Class 1 cells distinguish expansion from contraction on the basis of changing perimeter length. Class 2 cells are using the expansion and contraction flow field patterns to detect the change in distance between the moth and the flower. Those neurons provide elegant mechanisms for stabilising distance during hovering flight and are the basis of a model for a novel way to detect a change in distance between an observer and an object (Wicklein and Strausfeld, 2000 *Journal of Comparative Neurology* **424** 356–376; Wicklein and Sejnowski, 2001 *Neurocomputing* **38**–**40** 1595–1602).

[Supported by Feodor Lynen Fellowship by the Humboldt Foundation, NSF.]

Thursday

◆ Colour and patterns in bee vision

N Hempel de Ibarra, M Vorobyev¶ (School of Life Sciences, University of Sussex, JMS Building, Falmer, Brighton BN1 9QG, UK; ¶ Vision Touch and Hearing Research Centre, University of Queensland, Brisbane, QLD 4072, Australia; e-mail: nh45@sussex.ac.uk)

Colour vision of bees is trichromatic based on three photoreceptor types which are sensitive in the UV (S), blue (M), and green (L) range of the spectrum. Models of colour discrimination are available as a result of extensive studies on colour perception in bees. Achromatic pattern perception has also been heavily researched. But little had been done to bring the two areas together and the perception of chromatic patterns is almost an uncharted territory. Results of our psychophysical tests on free-flying bees are presented where we asked how they use chromatic and achromatic cues to detect coloured patterns and discriminate between them. We found that the spatial distribution of achromatic, L-receptor mediated contrast within a pattern has a strong influence on pattern detectability. The results can be explained by a neural model of achromatic object detectors with centre-surround receptive fields. Chromatic cues are involved in pattern discrimination and recognition while targets subtend large visual angles. In particular, these results help us to understand the evolutionary relationship between colours and patterns of flowers, and the visual system of bees, which are their most important pollinators.

◆ Evolution of colour and vision in butterflies

D G Stavenga (Department of Neurobiophysics, University of Groningen, Nijenborgh 4, NL 9747 AG Groningen, The Netherlands; e-mail: D.G.Stavenga@rug.nl)

Recent research demonstrates that butterflies have evolved from moths, which is corroborated by optical studies of butterfly eyes. The moth corneal nipple array exists in many butterfly families, but often in reduced form, and it is even absent in Papilionidae. Moth eyes have an extensive tapetum, which is present in reduced form in butterflies, or it is absent, as in Papilionidae. The inconspicuous moths possess colour vision, used for detecting flowers. Butterfly colour vision is in addition used for recognising the colourful wing patterns. A comparative survey of wing coloration of pierid butterflies, with UV photography and reflectance spectrophotometry, reveals the evolutionary changes in colours of the main subfamilies. Two quite different methods of sexual dichroism have developed among pierid butterflies. Butterfly compound eyes are composed of numerous ommatidia. The basic groundplan of butterfly eyes, encountered in Nymphalidae, exists of three types of randomly arranged ommatidia, with either 1 UV and 1 blue receptor, or 2 UV, or 2 blue receptors. All ommatidia contain 9 green receptors. In Pieridae, the set of short-wavelength receptors is expanded, and the green receptors have greatly diversified by spectrally selective filters. This has occurred even more elaborately in Papilionidae.

◆ Colour contrast and brightness contrast in foraging butterfly *Papilio xuthus*

M Kinoshita (School of Advanced Science, Graduate University for Advanced Studies, Shonan Village, Hayama, Kanagawa 240-0193, Japan; e-mail: kinoshita_michiyo@soken.ac.jp)

Papilio butterflies search for food by using colour vision including colour constancy. Here, tests were carried out to find how both colour and brightness of background affect the appearance of an object in *Papilio* colour vision. A *Papilio* was first trained to take nectar only at the green disk among disks of slightly different colours on black background. The green-trained *Papilio* could discriminate the training colour when the background was gray. However, on yellow background, the butterfly selected yellowish green; ie the yellowish green on yellow background appeared similar to the training green. This suggests that *Papilio* is subject to the phenomenon called colour contrast. *Papilio*s could also be trained to discriminate a colour disk depending on relative differences of brightness. The *Papilio* trained to darker red selected darker orange from brighter ones. When presented with two orange disks with the same brightness, one on dark gray and another on bright gray background, the *Papilio* selected the one on the bright gray. This indicates that the orange disk on bright gray appeared darker than the disk on dark gray, suggesting that brightness contrast is also contained in the *Papilio* colour vision.

◆ Nocturnal colour vision

A Kelber (Vision Group, Department of Cell and Organism Biology, Zoology, Lund University, Helgonavägen 3, S 22362 Lund, Sweden; e-mail: almut.kelber@cob.lu.se)

Humans and most vertebrates are colour-blind at night, because they have only one type of rod sensitive enough to allow for vision under scotopic conditions. Lizards, with a pure cone retina, are an exception, and this includes nocturnal geckos with a trichromatic retina. Nocturnal geckos can use colour vision in very dim light. Many insects also use three spectral types of photoreceptor in all light levels, and nocturnal moths with highly sensitive superposition eyes can have colour vision even in dim starlight. In contrast to nocturnal geckos, however, nocturnal moths

rely largely on other senses in addition to vision. Besides these two groups for which colour vision has been proven behaviourally, other animals may have nocturnal or dim light colour vision. Possible candidates include toads and frogs with two rod types, other nocturnal insect groups, spiders, and some deep-sea fish. Nocturnal colour vision is useful because the colour of light changes vastly between late twilight and nocturnal moon- or starlight. The changes of the illumination colour make achromatic vision much less reliable compared to colour vision.

◆ **The evolution of colour and polarisation vision in stomatopod crustaceans**

T W Cronin, M L Porter (Department of Biological Sciences, University of Maryland Baltimore County, 1000 Hilltop Circle, Baltimore, MD 21250, USA; e-mail: cronin@umbc.edu)

The stomatopod crustaceans (mantis shrimps) have a set of photoreceptors in retinas that are uniquely diverse and complex. Up to 16 different spectral classes are present, 10 operating at visible wavelengths (400 to 700 nm) and 6 more functioning in the ultraviolet (320 to 400 nm). Microspectrophotometric data suggest that each class is based on a different visual pigment, suggesting that as many as 16 different opsin genes should be expressed in the retina. We have begun to characterise the genetic diversity of the stomatopod opsin gene family, using a species for which most of the visual pigments and receptor sensitivities have already been described—*Neogonodactylus oerstedii*. We extracted RNA from retina and amplified putative opsin transcripts using primers. Sequences with unique 3' untranslated regions were used to construct labeled RNA probes for in-situ hybridisation to cryosections of retina. Initial investigations found 8 different transcripts, all of which localised to middle/long-wavelength receptor classes. Some receptors classes bound multiple probes, indicating that more than one opsin class may be expressed in single photoreceptor cells. Phylogenetic analyses of stomatopod opsin diversity show that most of these sequences cluster with other crustacean MWS/LWS opsins, with one clade clustering with insect and ostracod SWS sequences.

◆ **What can box jellyfish tell us about early eye evolution?**

D-E Nilsson (Department of Cell and Organism Biology, Lund University, Helgonavägen 3, S 22362 Lund, Sweden; e-mail: dan-e.nilsson@cob.lu.se)

The eyes of visually prominent animals such as vertebrates, cephalopods, and arthropods generally subserve a multitude of visual tasks. Naturally, early stages in the evolution of these complex visual organs must have been simpler, and subserved a smaller number of visual tasks. Hence, eye evolution is driven by a consecutive accumulation of visual tasks. Each task adds to the requirements on eye structure, making it gradually more complex. For these reasons, reconstructions of eye evolution should ideally be based on an understanding of the sequential addition of visual tasks. In particular, it is interesting to ask what the first visual tasks might have been, and what requirements these would have placed on the structure and function of early eyes. With this objective, we have investigated vision in a group of simple and phylogenetically basal animals, the box jellyfish. Behavioural experiments indicate that these animals use vision primarily for positioning in the habitat, and for negotiating obstacles. To serve these tasks, the eyes are tuned for low spatial frequencies and are colour-blind. The findings indicate that low resolution is not just sufficient, but in fact desirable in early stages of eye evolution.

◆ **Spectral tuning of vertebrate visual pigments**

D M Hunt, J K Bowmaker, J A Cowing, Livia dos S Carvalho, J W L Parry, S E Wilkie, W L Davies (UCL Institute of Ophthalmology, 11–43 Bath Street, London EC1V 9EL, UK; e-mail: d.hunt@ucl.ac.uk)

The visual pigments form a family of proteins (opsins) that bind either 11-cis-retinal or 11-cis-3,4-dehydroretinal to give rhodopsin or porphyropsin pigments, respectively. A rod pigment, and up to four classes of cone pigments are found in vertebrates, distinguished on the basis of spectral sensitivity and amino acid sequence of the respective opsins: long-wave-sensitive (LWS) with λ_{\max} of 500–570 nm, middle wave-sensitive (MWS) with λ_{\max} of 480–520 nm, and two short-wave-sensitive (SWS1 and SWS2) classes with λ_{\max} of 430–470 nm for SWS2 and 355–445 nm for SWS1. Spectral tuning of pigments depends on interactions between retinal and opsin. All visual pigments possess a Lys residue in transmembrane 7 that is covalently linked to the chromophore via a Schiff base. In pigments with λ_{\max} values >380 nm, the Schiff base is protonated. For longer-wave-sensitive pigments, spectral shifts are largely achieved by changes in residues that line the retinal binding pocket of the opsin and usually require a change in a polar or polarisable residue. In contrast, the major shift between the UV and violet seen in short-wave-sensitive pigments depends on changes in the protonation state of the Schiff base. The different molecular mechanisms involved in these processes are discussed in evolutionary and functional terms.

[Supported by Leverhulme Trust, Biotechnology and Biological Sciences Research Council.]

Thursday

◆ **Evolution of colour vision: The story of lost visual pigments**

M Vorobyev (Vision, Touch, and Hearing Research Centre, University of Queensland, Brisbane, QLD 4072, Australia; e-mail: m.vorobyev@uq.edu.au)

Colour vision appeared early in the evolution of vertebrates. Lampreys, the closest living relatives of the first vertebrates, have four types of cone visual pigments. These pigments were retained in many species of teleost fish, in diurnal reptiles, and birds. However, one or more cone pigments were lost in some fish species, in amphibians, geckos, crocodiles, and mammals, presumably when ancestors of these animals lived in dim light conditions. The loss of cone visual pigments in dim light could be explained in two different ways: (1) cone pigments were lost, because, in dim light, colour vision was not used; (2) in dim light, the reduction of the number of cone types improved colour vision. To test which of these is correct, I estimated the upper limit for the number of colours that can be discriminated by visual systems with different number of spectral types of cones. Discrimination threshold was set by the fluctuations in the number of absorbed quanta. Calculations show that in dim light the loss of a cone type may result in an increase of the number of colours that can be discriminated, eg in dim light dichromatic mammals may discriminate more colours than tetrachromatic birds.

◆ **Tetrachromatic colour vision in the Australian lungfish *Neoceratodus forsteri***

J Marshall, M Vorobyev, S P Collin, H J Bales, N S Hart (Vision Touch and Hearing Research Centre, School of Biomedical Sciences, University of Queensland, Brisbane, QLD 4072, Australia; e-mail: justin.marshall@uq.edu.au)

The visual system of the Australian lungfish *N. forsteri* has more in common with terrestrial vertebrates such as reptiles and birds, than with both sharks and bony fish. Features such as coloured oil droplets and multiple visual pigments indicate their phylogenetic allegiance with tetrapods, and suggest that the terrestrial trend for colour vision on land, with narrowly tuned spectral sensitivities, started in water. New aspects of the visual system and visual environment of *N. forsteri* are presented enabling a visual ecology for this species to be described for the first time. Using microspectrophotometry and spectrophotometry we describe: five visual pigment types (four cones with maximum sensitivities at 620 nm, 557 nm, 479 nm, and 374 nm, and a rod at 543 nm), the absorbance of two oil droplets (red and clear) and an ellipsoidal inclusion (yellow), ocular media absorbance (cornea and lens), spectral sensitivities which result from these observations, the light environment in rivers inhabited by *N. forsteri*, the colours of the fish, and the colours of some of their immediate surroundings. Using this battery of information we model the visual world of the Australian lungfish and compare its performance with that of terrestrial animals.

◆ **Ecological and neural constraints on perception of motion and the design of visual signals**

L J Fleishman, A Pallus (Department of Biology, Union College, Schenectady, NY 12308, USA; e-mail: fleishml@union.edu)

Many terrestrial vertebrates rely on visual detection of motion to direct their attention to important objects such as predators, prey, and conspecifics. However, windblown vegetation represents a ubiquitous source of visual noise in natural habitats. Visual motion perception is often carried out by simple neural circuits called correlation detectors, and behaviour experiments suggest that such circuitry may underlie attention responses in lizards. We created a model retina, consisting of a two-dimensional array of correlation detectors, and stimulated it with videos of relevant (food or prey) or irrelevant (windblown vegetation) motion. We adjusted the temporal parameters of the model to achieve effective discrimination of the two classes of motion. We also experimented with simple higher-order operations that further improved discrimination. We tested the model on videos of anoline lizards displaying in dense, moving vegetation. The model usually discriminated displays from the background. Thus, simple motion detection circuits can be designed to filter relevant from irrelevant natural movement. We hypothesise that the need for such discrimination has selected for neural motion detection circuitry with specific response properties, which, in turn, has selected for animal visual signals with patterns of motion that effectively stimulate these circuits.

◆ **Developmental programmes coordinating size and niche variations in the primate eye and retina**

B L Finlay, M A Dyer¶, M da Silva Filho§, J A P C Muniz#, L C L Silveira§ (Department of Psychology, Cornell University, Ithaca, NY 14853, USA; ¶ St Jude Children's Research Hospital, Memphis, TN, USA; § Universidade Federal do Pará, Centro de Ciencias Biologicas, Departamento de Fisiologia, 66075-900 Belém, PA, Brazil; # Centro Nacional de Primatas, Ananindeua, PA, Brazil; e-mail: blf2@cornell.edu)

The size and niche variations of New World monkeys offer the opportunity to compare variation of the mature visual system with the developmental alterations of retinogenesis that produce the

observed species differences. We have collected a number of measures of retinal cell number and conformation for six species of New World monkeys, including *Saguinus midas niger* (brain weight 9.7 g), *Callicebus moloch* (16.6 g), *Aotus azarae* (17.1 g), *Saimiri sciureus* (22.1 g), *Alouatta caraya* (42 g), and *Cebus apella* (71 g). In diurnal monkeys, eye size, rod, cone, and retinal ganglion cell numbers scale with brain size, but rod number increases at a much greater rate. A conserved order of retinal neurogenesis (cones first, rods last) may automatically produce relatively greater proliferation of rods in larger eyes, serving the separate adaptive requirements of cones and rods to maintain acuity and sensitivity respectively. Compared to diurnal monkeys, owl monkeys have fewer cones and ganglion cells but many more rods, and consequently greater photoreceptor convergence. The same order of neurogenesis that automatically adapts rod and cone numbers to eye size may also permit a coordinated alteration of proliferation for nocturnality and diurnality produced by shifting the onset and termination of cell proliferation with respect to the schedule of cell specification.

[Supported by CNPq 910149/NSF to LCLS and BLF and NSF IBN-0138113.]

◆ **Ecology and evolution of primate trichromacy**

D Osorio (School of Life Sciences, University of Sussex, Brighton BN1 9QG, UK;
e-mail: d.osorio@sussex.ac.uk)

Most animals have non-overlapping cone sensitivities, so why do the L and M cone sensitivities of primates strongly overlap? Intuitive considerations and mathematical modeling show that the non-overlapping receptors of a majority of animals are well-suited for discriminating a variety of colours. There are three main types of explanation for the unusual spectral distribution of primate cones: (i) there is a molecular constraint on the M cone moving to shorter wavelengths, (ii) there is a trade-off between the demands of luminance and colour vision, and (iii) primate trichromacy is optimal for colour vision, perhaps being adapted for a specific task such as finding ripe fruit. I give examples of plausible explanations, and ask how recent data on the polymorphic colour vision of New-World primates inform our understanding of the evolutionary function of primate colour vision.

FROM PERCEPTUAL TO ECONOMIC DECISIONS

◆ **Influence of prior probability on decision-making**

H R Heekeren (Independent Junior Research Group, Neurocognition of Decision-making, Berlin NeuroImaging Center and Max Planck Institute for Human Development, Lentzeallee 94, D 14195 Berlin; e-mail: heekeren@mpib-berlin.mpg.de)

In previous work, perceptual decision-making was investigated by manipulating sensory input, and motor output. The prior probability of the occurrence of an event is another critical variable in decision-making processes. For example, the response time in two-alternative forced choice tasks is speeded by prior probability, and V1 neurons in monkeys have been shown to track the likelihood of stimulus appearance. I discuss results of neuroimaging (EEG, fMRI) studies investigating (i) how and where prior probability is represented in the human brain, and (ii) at which stage of the decision-making process prior probability is integrated.

◆ **Brain dynamics of perceiving, deciding, and acting**

J V Schwarzbach (Laboratorio di Scienze Cognitive, Università degli Studi di Trento, via Tartarotti 7, I 38068 Rovereto, Italy; jens.schwarzbach@unitn.it)

Perceptual decision-making involves several processes at the same time: extraction of sensory information, decision-making, and response generation. In monkey physiology, a large body of evidence exists that links areas MT, LIP, and FEF/SEF/SC to these processes; human homologues are still debated. Functional magnetic resonance imaging (fMRI) allows investigating human brain functions noninvasively. fMRI has a lower spatial and temporal resolution as compared to animal physiology, but it gives us noninvasive access to the whole brain for studying the dynamics of perceiving, deciding, and acting. Moreover, making use of humans gives us greater flexibility in task-design and response modes. I deal with different methodological approaches to study how brain areas interact in perceptual decision-making.

◆ **Value-based decision making: using rich behavioural models to explore neural function**

L P Sugrue, G S Corrado, W T Newsome (Department of Neurobiology/HHMI, Stanford University School of Medicine, Fairchild Building, Room D200, Stanford, CA 94305, USA; e-mail: leo@monkeybiz.stanford.edu)

To forage successfully, animals must learn and maintain an internal representation of the value of competing options and link that representation to the neural processes responsible for decision-making and motor planning. To explore the neural substrate of valuation and action we have

Thursday

modeled the proximal behavioural mechanism underling the choices of rhesus monkeys in a simple task that requires them to forage for resources in a dynamic environment. The resulting model suggests that our monkeys have learned to maximise their foraging efficiency given the underlying statistics of reward availability in this task. Moreover, the hidden variables revealed by the model provide us with a framework with which to interpret neurophysiological and brain-imaging data collected while monkeys engage in the task and to isolate the specific contributions of different brain areas to value-based decision-making.

◆ **Social decision-making: Imaging healthy and disordered trust**

B King-Casas (Human Neuroimaging Laboratory, Baylor College of Medicine,
1 Baylor Plaza, S104, Houston, TX 77030, USA; e-mail: bkc@hnl.bcm.tmc.edu)

Recent advances in social neuroscience are beginning to characterise the neural substrates of cooperative and non-cooperative social exchange. I discuss two studies of healthy and disordered interpersonal exchanges of trust. In the first study, trust was probed in a group of healthy volunteers engaged in an iterated version of the 'Trust Game'—a paradigm borrowed from behavioural economics. In the second study, maladaptive exchanges of trust were examined in patients with borderline personality disorder.

◆ **Social context and decision making: fMRI study of advertising effects**

V Klucharev, A Smids[¶], G Fernandez[§] (ERIM and [§]The F C Donders Center for
Cognitive Neuroimaging, PO Box 9101, NL 6500 HB Nijmegen, The Netherlands;
[¶]RSM Erasmus University, PO Box 1738, NL 3000 DR Rotterdam, The Netherlands;
e-mail: v.klucharev@fcdonders.ru.nl)

In daily life our decisions are frequently modulated by persuasive communication. Advertising (ads) is an excellent model to study persuasion. Recently an 'expertise' model was suggested in order to explain role of celebrities in effective ads. Model predicts that if the presenter is perceived to be an expert in the category of the endorsed product, then the presenter, regardless of any other characteristics he/she may be perceived to have, will increase persuasion. We simulated ads containing both photos of various celebrities and everyday products. During fMRI session, we presented female subjects with photos of celebrities followed by photos of everyday products. We hypothesised that the high presenter expertise enhances both buying intention and memory for the product. We found a significant behavioural effect of the presenter (celebrity) on the memory and buying intention for the product that lasted at least 24 h. Significant interaction of presenters' expertise with buying intention for products was found at dorsal caudate nucleus. Presenter expertise also enhanced memory-related activity of medial temporal lobe. Our data suggest that contextual social information modulates activity in neural network known to be involved with memory encoding (hippocampus), learning, and processing of perceived fairness of social partners (dorsal striatum).

BINOCULAR VISION, STEREOPSIS

◆ **Structural changes in visual cortex of strabismic cats**

S V Alexeenko, S N Toporova, P Y Shkorbatova (Vision Physiology Laboratory,
Pavlov Institute of Physiology, Russian Academy of Sciences, nab. Makarova 6,
199034 St Petersburg, Russia; e-mail: sveta@va1021.spb.edu)

It is known that horizontal connections in the visual cortex of early-strabismic animals extend between neurons activated by the same eye. We present data demonstrating that the length of such connections for cortical ocular dominance columns (ODCs) receiving inputs from contralateral or ipsilateral, normal or deviated eye is differently modified by strabismus. Tangential distribution of retrogradely labelled cells in area 17 of unilateral and bilateral convergent strabismic cats (SCs) was assessed after micro-iontophoretic horseradish peroxidase injections into single ODCs. Ocular dominance of the columns was evaluated by analysis of labeling in dorsal LGN laminae. In both groups of animals, the shortening of connections was revealed for ODCs driven by the contralateral eye. The length of connections of ipsilateral eye ODCs was more variable. In unilateral SCs they were enlarged for intact and shortened for deviated eye ODCs. These changes were found along the projection of the eye deviation axis. Enlargement of connections along orthogonal axis was found for ipsilateral eye ODCs in SCs having eye torsion. Interhemispheric connections revealed mainly for ipsilateral eye ODCs were enlarged. Thus cortical connections of ODCs receiving inputs via evolutionary older (crossed in chiasm) and relatively younger (uncrossed) visual pathways undergo different changes.

[Supported by Russian Foundation for Basic Research grants 03-04-48258, 06-04-49391.]

- ◆ **Impairment of binocular vision alters differently neural basis for stereopsis along the visual midline during development and at adulthood: contribution of the corpus callosum**
C M-T Milleret (Laboratoire de Physiologie de la Perception et de l'Action, Collège de France, 11 place Marcelin Berthelot, F 75005 Paris, France; e-mail: chantal.milleret@college-de-france.fr)

Neurons activated through the corpus callosum in cat visual cortex are almost entirely located at the 17/18 border. They display receptive fields (RFs) distributed along the central vertical meridian of the visual field. Most of these cells are binocular, and many of them are activated both from the contralateral eye through the corpus callosum, and from the ipsilateral eye via the direct retino-geniculo-cortical pathway. These two pathways do not carry exactly the same information, leading to interocular disparity between pairs of RFs along the visual midline. A few weeks of unilateral paralytic strabismus surgically induced early in life leads to an increased interocular disparity between these pairs of RFs at adulthood. When induced at adulthood, it also increases such disparity, but in a different way compared to the previous condition. Here, both conditions are compared, with an analysis of how strabismus may alter differently stereopsis along the visual midline as function of age.

[Supported by 'Human Capital and Mobility' grant ERBCHRX-CT-940597 from the European Community]

- ◆ **Visual misperceptions and cortical binocularity loss**
R Sireteanu (Department of Neurophysiology, Max Planck-Institute for Brain Research, Deutschordenstrasse 46, D 60528 Frankfurt, Germany; e-mail: sireteanu@mpih-frankfurt.mpg.de)

Visual misperceptions reported by humans with developmental impairments in binocular vision were investigated with a combination of psychophysical, computational, and brain-imaging techniques. In psychophysical experiments, the spatial distortions and temporal uncertainties were characterised in a large number of subjects with impaired binocular vision (strabismic and/or anisometropic amblyopes, strabismics with alternating fixation). The resulting descriptions were visualised with automated computer simulations. In a further series of experiments, the monocular activation and the residual binocular brain activity of these subjects were investigated by functional magnetic resonance imaging (fMRI). Most amblyopic subjects showed significant spatial distortions of the visual percept of their amblyopic eyes. In about half of the amblyopic subjects, these misperceptions were temporally stable. The remaining subjects experienced temporal instabilities either in addition or in the absence of spatial distortions. Subjects experiencing subjective distortions also showed impaired cortical activation at higher cortical levels on the ventral visual pathway, especially in the lateral occipital complex (LOC). Subjects with impaired stereopsis showed significantly reduced interocular transfer of adaptation, as assessed with an fMRI adaptation paradigm. These results point to a cortical involvement, affecting mainly the higher extrastriate cortical levels, in subjects with compromised binocularity.

[Supported by Deutsche Forschungsgemeinschaft SI/17-1,2,3]

- ◆ **Deficiencies of higher-order motion perception in children with amblyopia**
D E Giaschi, C S Ho¶, P Cavanagh§ (Department of Ophthalmology and Visual Sciences [¶ Department of Psychology], University of British Columbia, 4480 Oak Street, Vancouver, BC V6H 3V4, Canada; § Department of Psychology, Harvard University, 33 Kirkland Street, Cambridge, MA 02138, USA; e-mail: giaschi@interchange.ubc.ca)

Disruptions in binocular vision leading to amblyopia are known to impair many aspects of spatial vision, usually in only one eye. Motion perception may also be compromised, with large deficits in both amblyopic and non-amblyopic fellow eyes. We found a relative preservation of low-level motion perception and transient attention, but notable deficits in high-level attentive tracking, even in the fellow eye, of children with strabismic or anisometropic amblyopia. These findings implicate binocular regions of posterior parietal cortex in amblyopia.

- ◆ **Improvement of binocular functions by means of interactive software**
V M Kononov, T A Podugolnikova¶, G I Rozhkova¶ (Department of Ophthalmology, State Pediatric Medical Academy, Litovskaya 2, 194100 St Petersburg, Russia; ¶ Institute for Information Transmission Problems, Russian Academy of Sciences, Bolshoi Karetnyi 19, 127994 Moscow, Russia; e-mail: wwoo@yandex.ru)

Normal human binocular vision implies precisely coordinated activity of the oculomotor system and a very complex visual system containing parallel pathways with various modules for information processing. Therefore successful treatment of binocular disorders implies restoration of this coordinated activity in every respect. In such treatment, computer interactive software could

Thursday

serve as a universal and powerful means providing fine diagnostics and individually optimised procedures. We have used the original combined software AKADEMIK for treatment of strabismus and functional central scotoma (due to suppression), for extending the fusion range and developing stereovision. On one hand, AKADEMIK allows us to realise all the procedures traditionally accomplished by means of synoptophore and, on the other hand, it makes possible a number of new procedures using such specific computer-generated patterns as random-dot stereograms and movement in two dimensions. Squinting eye deviations up to 10° could be removed in 20 training sessions, and larger deviations (10° – 20°) in 30–40 sessions. Elimination of functional scotoma usually took 15–20 sessions. Fusion range typically reached normal extension in 10–15 sessions. The rate of stereovision restoration/development depended heavily on the type of strabismus (esotropia/exotropia) and on its etiology. In the cases of exotropia, normal stereovision could be achieved after 3–4 sessions.

◆ **Central suppression at near vision in presbyopic subjects**

B Granger-Donetti (Department of Vision Sciences, Essilor R&D Optique Monde, 57 avenue de Condé, F 94106 Saint-Maur Cedex, France; e-mail: donettib@essilor.fr)

Presbyopia has a major impact on binocular vision. Physiological loss of accommodation may induce reduction of fusional capabilities, especially in near vision. Even if presbyopic subjects are expected to make more efforts to maintain binocular fusion, they do not complain more than young subjects (Pickwel et al, 1991 *Ophthalmic and Physiological Optics* **11** 291–296). Previous works suggested that central suppression allowed presbyopic subjects to avoid troubles due to binocular disorders. To test this hypothesis, the frequency of suppression among sixty-eight presbyopic volunteers divided into three groups of age was studied. Results showed that 81% of the subjects exhibited suppression. This proportion was equally distributed between the three age groups. Size and stability of suppression areas were also recorded with the use of the Mallett unit. These properties varied with age, refractive error, binocular balance, and modification of prescription at near vision. Finally, in the group of subjects who were not concerned by suppression, binocular profile seemed to be more efficient. The present results confirm the original hypothesis and suggest that central suppression could be a binocular strategy for presbyopic patients to avoid symptoms caused by binocular imbalance during presbyopia.

CROWDING (INCLUDING LATERAL MASKING, ILLUSORY CONJUNCTIONS, SURROUND SUPPRESSION, AND ATTENTION)

◆ **Crowding and its cure: Isolating to recognise**

D G Pelli (Department of Psychology and Neural Science, New York University, 6 Washington Place, New York, NY 10003, USA; e-mail: denis.pelli@nyu.edu)

It is suggested that the elementary step in object recognition is to recognise the combination of all the features in a region defined by an isolation field, ignoring what is outside. This idea allows new attacks on old problems in object recognition.

[Supported by National Institutes of Health R01EY4432.]

◆ **First-order and second-order classification image analysis of crowding**

B S Tjan, A S Nandy¶ (Department of Psychology and Neuroscience Graduate Program [¶ Department of Psychology], University of Southern California, Los Angeles, CA 90089, USA; e-mail: btjan@usc.edu)

A letter target presented in the periphery can become unrecognisable when flanked by other letters. We used a modified classification-image method to compare first-order and second-order visual features used by an observer in a letter-identification task ('o' vs 'x' embedded in white noise) with and without other flanking letters. We minimised the adverse effect of positional uncertainty on classification images, which can be substantial in the periphery, by presenting the letter targets at a sufficiently high contrast and by analysing separately the classification sub-images from different stimulus-response categories (Tjan and Nandy, 2006 *Journal of Vision* **6** 387–413). We then extracted second-order visual features by computing pixel-wise correlation between all pairs of pixels of a given displacement from each noise field of each stimulus-response category. We found that the shapes of the first-order templates under the crowding condition were undistorted and comparable to those in the non-crowded condition. Interestingly the spatial correlation maps, which depicted the second-order features, were much sparser in the crowding condition although the size and slopes of the persistent features remained roughly the same as the corresponding ones in the non-crowded condition. These results suggest that one component of crowding is an inability to bind together sparse second-order features.

[Supported by NIH/NEI R03-EY016391.]

◆ **Effects of the task on crowding**

A Huckauf (Faculty of Media, Bauhaus University Weimar, Bauhausstrasse 11, D 99423 Weimar, Germany; e-mail: anke.huckauf@medien.uni-weimar.de)

Relative to the recognition of isolated letters, recognition performance for a flanked target letter is impaired in the visual periphery. Theoretical explanations concerning this so-called crowding or lateral masking effect comprise the assumption that failures during feature integration mainly underlie crowding. Since feature processing is usually thought of as an automatic early sensory process preceding object recognition, current approaches imply that crowding is due to failures during automatic sensory processing. I present data showing that task sets determine the recognition performance of flanked letters. Targets were defined either via their form (curved, angular) or via their category (letter, digit). For same strings, recognition performance depended on the target definition and the task: whereas form-defined targets were detected and localised better than category-defined ones, the opposite was true for identification. This demonstrates that crowding effects do not automatically arise but are determined by task sets.

◆ **Foveal crowding effect is not simple masking**

V M Bondarko, M V Danilova (Pavlov Institute of Physiology, Russian Academy of Sciences, nab. Makarova 6, 199034 St Petersburg, Russia; e-mail: vmbond@gmail.com)

We carried out psychophysical experiments to show that at the resolution limit of the visual system crowding effects are not size-invariant and spatial-frequency-selective. The targets were rectangular gratings consisting of two black bars or Landolt Cs. These gratings were surrounded by vertical or horizontal gratings having the same or high spatial frequencies. On each presentation, the orientation of the surrounding gratings was either fixed or varied randomly. Landolt Cs were surrounded by tangential bars. The observers' task was to detect the orientation of a central target. The grating discrimination depended on the spatial frequency of the distracting gratings and the way their orientation was varied. Maximal inhibitory areas were obtained when the surrounding gratings had the same frequencies as the test and random orientations. The areas were about twice smaller when their orientation was fixed; similar areas were measured in the case when minimally resolved Landolt C was the target. When the Landolt C was used as a target, the inhibitory areas diminished with increasing sizes of the test, which contradicts the lateral-masking hypothesis. Such results can be explained by assuming different spatial elements that perform initial processing of the test stimulus under different experimental conditions.

[Supported by RFBR grant 06-07-89137-a and RFH grant 06-06-00252a.]

◆ **Crowding and surround suppression: not to be confused**

Y Petrov, A V Popple[¶], S P McKee (Smith-Kettlewell Eye Research Institute, 2318 Fillmore Street, San Francisco, CA 94115, USA; [¶]School of Optometry and Helen Wills Neuroscience Institute, University of California at Berkeley, Berkeley, CA 94720-2020, USA; e-mail: yury@ski.org)

Crowding and surround suppression share many similarities, which suggests the possibility of a common mechanism. Despite decades of research there has been little effort to compare the two phenomena in a consistent fashion. A recent study by Levi et al (2002 *Journal of Vision* 2 167–177) argues that the two are unrelated, because crowding effects can be much stronger than suppression effects. Here we report experiments in which the same Gabor target was used both for orientation identification (crowding) and contrast detection (suppression) tasks. Corresponding masks were a plaid made of two orthogonal Gabors and a grating half-annulus. In agreement with early crowding studies (eg Bouma, 1973 *Vision Research* 13 767–782), we found that an outward mask is much more effective than an inward mask for the orientation identification task. Notably, no such anisotropy was observed for the contrast detection task, commonly used to measure surround suppression. This demonstrates that surround suppression and crowding are, indeed, two distinct phenomena. We used this characteristic anisotropy to show that a popular crowding paradigm in which target contrast is varied to measure crowding is confounding it with surround suppression. Surround suppression apparently dominates at low contrasts, which would explain some of the reported similarities between the two phenomena.

◆ **LWS: Three processes in reading**

K A Tillman, D G Pelli (Department of Psychology and Neural Science, New York University, 6 Washington Place, New York, NY 10003, USA; e-mail: kat243@nyu.edu)

The isolation field idea, which explains crowding, enables new attacks on old problems. Here we tackle reading. To read, we use information from letters, words, and sentences. Specifically, we can identify the next word in a passage from the identities of the letters (L) that make up the word, from the shape of the word (W), or from the other words that make up the sentence (S).

Thursday

Here, we manipulated text to selectively remove each of the three kinds of stimulus information. We used crowding to find letter substitutes that preserve W while knocking out L. The results show that the three word identification processes (L, W, and S) make independent additive contributions to reading rate in words per minute.

[Supported by R01-EY004432 to DP]

◆ **Crowding, reading, and developmental dyslexia**

M Martelli, G Di Filippo, D Spinelli¶, P Zoccolotti (Department of Psychology, University of Rome 'La Sapienza', 78 via dei Marzi, I 00185 Rome, Italy; ¶ University Institute for Motor Sciences [IUSM], 15 piazza De Bosis, I 00194 Rome, Italy; also IRCCS Fondazione Santa Lucia, 306 via Ardeatina, I 00179 Rome, Italy; e-mail: Marialuisa.Martelli@uniroma1.it)

We tested the hypothesis that abnormally large isolation fields (crowding) are responsible for the slow reading characteristic of Italian dyslexia. We studied thirty Italian dyslexics and thirty age-matched controls. Threshold contrast for identifying letters and words as a function of stimulus duration showed that dyslexics were slower than controls for words but not for letters. The critical character size (CPS), ie the increment of reading rate up to a critical character size with no further improvement thereafter (Chung et al, 1998 *Vision Research* **38** 2949–2962) of dyslexics children was twice the size of controls CPS. This finding is consistent with a difference in the size of the isolation fields between dyslexics and controls. To directly test crowding, we measured the spacing between the target letter and the flankers needed to obtain a fixed level of performance as a function of eccentricity in both groups of observers. We found that isolation field size scales with a proportionality of 0.5 in the control group, and a much larger proportionality (0.9) in the dyslexic group. We conclude that visual crowding limits reading rate in Italian dyslexics.

◆ **Grouping of contextual elements that affect Vernier thresholds in the human fovea**

M Malania, M H Herzog¶, G Westheimer§ (Laboratory of Vision Physiology, I Beritashvili Institute of Physiology, Georgian Academy of Sciences, Gotua 14, 0160 Tbilisi, Georgia; ¶ Laboratory of Psychophysics, Brain–Mind Institute, École Polytechnique Fédérale de Lausanne, CH 1015 Lausanne, Switzerland; § Department of Molecular & Cell Biology, University of California, 142 Life Sciences Addition #3200, Berkeley, CA 94720-3200, USA; e-mail: mmalania@yahoo.com)

Thresholds for discriminating offsets between parallel abutting lines (Vernier acuity) are several times smaller than the diameter of retinal photoreceptors, a phenomenon known as hyperacuity. Of the various means of gaining insight into the mechanisms of Vernier acuity, a favorite is the examination of the manner in which contextual stimuli interact to modify thresholds. For example, it has been shown that single flanking lines on each side of the Vernier can strongly raise the thresholds. We presented various flank configurations and measured their capacity to interfere with Vernier acuity. Surprisingly, this interference decreased if the number of flanking lines increased. This reduction can be reversed, however, by inserting a gap in the array of flanking lines revealing that grouping of flanks into a contextual cluster reduces the interference. Accordingly, we show that if the gap singles out the flanks next to the Vernier, thresholds are as high as if these flanks were presented alone. These results are corroborated by subjective ratings: the more the Vernier stands out from a configuration of flanks, the lower are offset discrimination thresholds.

[Supported by the Volkswagen Foundation and SNF]

◆ **Clutter without crowding: The effect of background statistics on visual learning**

J Fiser, R N Aslin¶ (Center for Complex Systems and Department of Psychology, Brandeis University, Waltham, MA 02454, USA; ¶ Department of Brain and Cognitive Sciences and Center for Visual Science, University of Rochester, Rochester, NY 14627, USA; e-mail: fiser@brandeis.edu)

Two views have been put forward to explain crowding: (a) masking hinders feature detection owing to the limited capacity of attention to elements in multi-element scenes, and (b) interference hinders feature integration of spatially adjacent elements by complex feature detectors. We approach this problem by separating the effect of crowding from that of clutter in a visual learning paradigm. We define crowding as the number of visual elements in a fixed area, and clutter as the level of statistical relatedness of those elements to each other across many scenes. We tested how increasing the level of clutter while not changing crowding affects the ability to extract new visual representations from previously unfamiliar scenes. Subjects were profoundly affected by changes in clutter; they learned representations from scenes composed of fewer related structures (low clutter) much easier than from scenes with many unrelated smaller structures (high clutter). This was true even though the actual structures they had to learn were exactly the

same, and the low and high clutter backgrounds were perceptually indistinguishable. This suggests that, independent of crowding, interference due to subjective clutter, rather than masking or the actual statistical structure of scenes, determines visual learning and immediate perception. [Supported by NIH HD-37082.]

◆ **A possible analogue of spatial crowding in time**

M J Morgan (Applied Vision Research Centre, City University, Northampton Square, London EC1V 0HB, UK; e-mail: m.morgan@city.ac.uk)

Eight stimuli (lines) were presented sequentially at a rate of one stimulus every 0.8 s. All the stimuli had the same length except for one, which was either shorter or longer than the standard. After all the stimuli had been presented the observer had to indicate whether the odd man out was shorter or longer (binary classification task). Accuracy was improved by inserting a 0.8 s blank interval between stimuli. A possible explanation is that each stimulus requires an attention-consuming comparison with an internal standard, and that this is aided by a brief interval off-line. Control experiments to test alternative explanations are described.

SYMPOSIUM

COLOUR SPACE: ITS STRUCTURE AND BIOLOGICAL BASIS—IN HONOUR OF PROF. E N YUSTOVA

◆ **Foveal distribution of L and M cones**

J Krauskopf (Center for Neural Science, Room 809, New York University, 4 Washington Place, New York, NY 10003, USA; e-mail: jkr@cns.nyu.edu)

The theoretical importance of the relative number and distribution of the L and M cones in the retina has inspired a number of elegant experiments. It would be particularly valuable to measure the distribution in the fovea; however, most of the methods used determine L and M cone distributions by averaging across large regions of the retina. In some cases this method is not applicable in the fovea. In order to determine L and M cone distributions in the fovea, tiny, brief, weak flashes of monochromatic lights were presented, which varied in perceived colour from flash to flash. By a Stilesian increment threshold experiment, the wavelength to which the L and M cones are intrinsically equal in sensitivity was determined. The ratio of the frequency with which flashes of that wavelength are called red and green provides an estimate of the numerical L to M ratio. The method is immune to variations in pre-retinal filtering and the spectral location of the cone sensitivity functions.

◆ **Cone inputs and chromatic signals in macaque ganglion cells**

B B Lee, H Sun (Biological Sciences, SUNY Optometry, 33 West 42nd Street, New York, NY 10036, USA; e-mail: blee@sunyopt.edu)

Chromatic signals are generated in the retina of primates by opponent interaction of the different cone types. These are generated by a retinal connectivity which is not fully understood. There are two views how cone opponent signals are generated: they could come about owing to 'random wiring' of cones to ganglion cells, or there are—as yet unknown—mechanisms which confer total (or substantial) cone specificity on the opponent signal, over and above what might be expected on an anatomical basis. We review evidence which supports specific connectivity. For example, it appears that S cone input is specifically avoided by cells of the parvocellular (PC) and magnocellular (MC) pathways. With L, M opponent signals and the PC pathway, physiological and anatomical data are inconsistent, but we argue that some degree of specificity must be present, although it may not be complete. Finally, physiological and psychophysical evidence obtained with a novel grating stimulus suggests that this specificity is carried over to output signals; achromatic and chromatic spatial information is strictly segregated into the MC and PC pathways up to the highest spatial frequencies. The primate retina thus takes great care in segregating its cone and chromatic signals into highly specific pathways.

[Supported by NEI 13112.]

◆ **Colour discrimination ellipses measured with transient visual evoked potential**

L C L Silveira, B D Gomes, G S Souza, A R Rodrigues, C A Saito, M da Silva Filho (Universidade Federal do Para, Centro de Ciencias Biologicas, Departamento de Fisiologia, 66075-900 Belem, Para, Brazil; e-mail: luiz@ufpa.br)

We measured human colour discrimination ellipses using transient visual evoked cortical potential (tVECP). CIE 1976 chromaticity diagram was used. Six normal trichromats and one deutan were tested. Horizontal isoluminant sine-wave gratings were made from colour pairs located along four different colour directions radiating from two reference points, 2 cycles deg⁻¹, onset/offset presentation mode. Each subject performed HFP assessment to determine his/her isoluminance

Thursday

condition for all colour axes. Monocular N1 tVECP amplitudes were plotted against colour distances to find colour thresholds by extrapolation to the null amplitude value. Psychophysics thresholds were obtained by using the same stimulus with an onset/offset and a static presentation mode. Furthermore, thresholds were estimated by means of the Mollon–Reffin Test. We found the best elliptical function to fit the data. We found a negative deflection in the tVECP related to chromatic difference. tVECP thresholds were similar to those obtained with psychophysics by using sinusoidal stimuli for all subjects, however smaller than those obtained with the Mollon–Reffin Test. For the deutan subject, ellipses had larger size, higher ellipticity, and were oriented towards the deutan copunctal point. The present work extends the use of tVECPs as a tool to evaluate human colour vision.

[Supported by CNPq-Pronex/Sectam-Funtec, Capes-Procad, Capes-Prof. LCLS is a CNPq research fellow.]

◆ **Spatial contrast in colour: Nonlinear effects in blackness induction**

G V Paramei, D L Bimler¶, C A Izmailov§ (Institute of Psychology, Darmstadt University of Technology, Alexanderstrasse 10, D 64283 Darmstadt, Germany; ¶ Department of Health and Human Development, Massey University, Private Bag 11-222, Palmerston North, New Zealand; § Department of Psychophysiology, Moscow Lomonosov State University, Mokhovaya 8/5, 103009 Moscow, Russia; e-mail: paramei@psychologie.tu-darmstadt.de)

Colour appearance changes when spatial contrast is involved: a more luminous surround induces blackness in a chromatic stimulus. We investigated the relationship between colour appearance and surround luminance. Monochromatic stimuli from 405 to 675 nm were presented with a broadband annulus at six levels of luminance contrast. Subjects assessed target colour using the colour-naming method; data were analysed with multidimensional scaling. This resulted in a 4-D colour space: two dimensions corresponded to the traditional red–green and blue–yellow perceptual systems. To accommodate the achromatic aspect of stimulus appearance, two orthogonal dimensions were required: One, ranging from black to white, was related to stimulus brightness, the other was identified as desaturation. We found that contrast-induced subjective blackening altered the chromatic aspect of the stimuli—their hue—in a manner comparable to the Bezold–Brücke effect, or hue change with objective luminance reduction. Also, the contrast-induced blackening affected saturation of the target colour. The interaction between stimulus hue and saturation differed, however, from the Abney effect, or desaturation resulting from objective decrease of luminance. These findings demonstrate nonlinear effects of blackness induction in stimulus appearance and have implications for the locus of spatial-contrast processing within the cortical pathways of colour perception.

◆ **Using Stroop tasks to reveal the structure of colour space**

H E Smithson, L T Sharpe¶, A Stockman¶ (Department of Psychology, Durham University, South Road, Durham DH1 3LE, UK; ¶ Institute of Ophthalmology, University College London, 11–43 Bath Street, London EC1V 9EL, UK; e-mail: hannah.smithson@durham.ac.uk)

In the reverse Stroop task, observers are instructed to ignore the ink-colour in which a colour-word is presented (the distractor colour) and to respond to the meaning of the colour-word (the target). Reaction times (RTs) are faster with congruent combinations, when distractor and target match, than with incongruent combinations, when they do not match. We have previously shown that RT differences in a reverse Stroop task can reveal perceptual transitions between colour categories. The transitions we measured were independent of stimulus and response sets, and qualitatively similar to hue-scaling data. Now, using the same reverse Stroop task, we have mapped-out the regions of colour space that correspond to the basic colour terms identified by Berlin and Kay. We sampled a set of 64 distracting ink-colours, paired in random order with each of the target colour-words, and measured RTs for selecting the correct response patch using a joystick. The magnitude of reverse Stroop interference provides an objective index of the compatibility between the distracting ink-colour and the target colour-word. The reverse Stroop task can be used to quantify the mapping between cone-excitation space and a cognitive colour space defined at an advanced level of neural processing.

◆ **Do tetrachromatic women exist?**

G Jordan, N Atkinson, J D Mollon¶ (School of Biology and Psychology, University of Newcastle, Henry Wellcome Building, Framlington Place, Newcastle upon Tyne NE2 4HH, UK; ¶ Department of Experimental Psychology, University of Cambridge, Downing Street, Cambridge CB2 3EB, UK; e-mail: Gabriele.Jordan@ncl.ac.uk)

About 12% of women are carriers of an X-linked red/green hybrid gene that encodes a photopigment with a spectral sensitivity somewhere between those of the normal M and L cone

photopigments. Owing to random X-chromosome inactivation (Lyon, 1961 *Nature* **190** 372–373), the retinal mosaic of such a carrier will contain more than three types of cone. We ask whether such a woman can become a functional tetrachromat and exhibit enhanced colour discrimination. Our subjects perform a three-alternative temporal forced-choice task, in which two of the stimuli are monochromatic (590 nm) while the third is a mixture of two monochromatic lights (550 nm plus 670 nm). The stimulus fields are 2 deg circular patches centred on the fovea and are presented in rapid succession in Maxwellian-view. Chromatic aberrations are masked by an annulus containing temporal chromatic noise. Subjects are asked to identify which of the triplet of stimulus fields is the mixture. In a random sequence, the program tests different combinations of (a) the red/green mixture ratio and (b) the radiance of the monochromatic field. For the normal, there is a combination of (a) and (b), equivalent to the Rayleigh match, where performance is at chance. A tetrachromat should not fail at any combination.

[Supported by Leverhulme Trust.]

◆ **New colour-vision testing plates by E N Yustova and their clinical use**

V V Volkov (Department of Ophthalmology, Military Medical Academy, Klinicheskaya 1, 194044 St Petersburg, Russia; e-mail: vv_volkov@hotmail.com)

In the 19th century different trades required large-scale testing of colour vision. In the first half of the 20th century two sets of colour-vision testing plates became most popular: pseudochromatic plates developed by Ishihara and those developed by E B Rabkin. These plates were designed and widely used for detecting inherited colour anomalies, but they were unable to assess changes in colour sensitivity which was required by practising clinicians. Such plates were developed by E N Yustova on the basis of Nyberg's colour addition theory. They were designed to test separately three colour receivers (R, G, B coordinates), and made it possible to estimate not only the presence of a particular kind of the receivers, but also their sensitivity on a 4-point scale. The first set of these plates used colour samples from an atlas containing 1000 colours developed at the Soviet Union State Metrological Institute in St Petersburg and was tested in the Military Medical Academy on patients with ophthalmological and neurological diseases. Yustova's plates proved to be an effective means for colour-vision estimates in clinical practice and for following dynamic recovery in the course of treatment.

HAND, ARM, AND BODY COORDINATION IN VISUAL SPACE

◆ **Prism adaptation and normalization of eye-hand coordination**

M Fahle, S Wischhusen, K Spang (Department of Human Neurobiology, Bremen University, Argonnenstrasse 3, D 28211 Bremen, Germany; e-mail: mfahle@uni-bremen.de)

We argue that perceptual learning not only improves detection and discrimination of stimuli, but also adjusts and normalises sensory signals stemming from different sense organs, such as in the so-called prism adaptation. Subjects had to either point to, or else throw a ball towards a target. After recording baselines, we used prisms shifting the visual world in horizontal direction. Subjects initially pointed or threw off target, but adjusted within less than ten movements. After removal of the prisms, an aftereffect occurred in the opposite direction, persisting for less than ten movements, too. Surprisingly, the size of the aftereffect did depend on the angle between head and trunk: rotations between head and trunk were only incompletely compensated for, i.e. a change in head–trunk angle strongly modified the size of the aftereffect when pointing towards a target. Moreover, prism adjustment did not transfer between the pointing and the throwing tasks. Despite the identical sensory inputs in both tasks, subjects had to re-learn the prism adjustment when performing the new type of movement. We conclude that 'prism adaptation' should be relabeled 'prism adjustment' since it involves complex adjustments of sensorimotor programs, possibly by changing the input gain of proprioceptive inputs.

◆ **Two new visual methods for generating phantom sensations in amputees and normal subjects:**

Multiple reflections from three-panel mirrors, and mirror images flickering in counterphase

D H Peterzell, R E Cone¶, J R McQuaid§, V S Ramachandran (Department of Psychology and Center for Brain and Cognition, University of California San Diego, 9500 Gilman Drive, La Jolla, CA 92093, USA; ¶ Clinical Psychology, Alliant International University, San Diego, CA 92131-1799, USA; § VA San Diego Healthcare System and Department of Psychiatry, University of California San Diego, 3350 La Jolla Village Drive, San Diego, CA 92161, USA; e-mail: peterzell@psy.ucsd.edu)

A mirror-box apparatus has been used previously to reduce or eliminate phantom limb pain in amputees and to generate phantom sensations (eg tingling) in normal subjects. We have created two new apparatus that generate intense phantom sensations in four patients (with missing left arms) who experienced little relief following standard mirror-box treatment. One uses three vertical mirrors, with panes oriented at angles that enable viewers to see unusual reversed mirror

Thursday

images of themselves from the side. The other uses a real-time video image of the individual, and flickers the image between a normal image and a mirror image. When subjects move their remaining arm and hand while viewing the modified images, they experience sensations and movement in the missing limb. Although subjects did not experience referred sensations of the hand and arm on the ipsilateral check prior to stimulation, they experienced strong referred sensations during and after stimulation. One subject reports complete and permanent cessation of phantom pain after the use of the tri-partite mirror. Both methods induce sensations of tingling, movement, and temperature change in the hands and arms of some normal subjects. We speculate that the human mirror neuron system plays a role in producing these effects.

◆ **Visual control of the hand when intercepting moving targets**

E Brenner, J B J Smeets (Faculty of Human Movement Sciences, Vrije Universiteit, Van der Boechorststraat 9, NL 1081 BT Amsterdam, The Netherlands; e-mail: e.brenner@fbw.vu.nl)

We are so good at intercepting moving targets that we often do not realise how complicated a task it can be. Even the simple issue of when and where to make contact with the target is not at all trivial, because, although the two are obviously interdependent, there is no single correct choice of a combination of time and place. There can be many reasons for choosing a certain combination, just as there can be many reasons for choosing a certain movement trajectory and velocity profile. We discuss some of these reasons and try to determine how flexible people are in selecting a strategy, and whether the strategy that they select is likely to be optimal in terms of performance. For instance, do people choose a different trajectory if there are obstacles nearby?

◆ **Integration of information across the visual scene in the control of prehension**

P B Hibbard, P Scarfe, S J Watt¶ (School of Psychology, University of St Andrews, St Andrews, Fife KY16 9JP, Scotland, UK; ¶ School of Psychology, University of Wales, Bangor, Gwynedd LL57 2AS, Wales, UK; e-mail: pbb2@st-andrews.ac.uk)

In order to reach out and grasp an object, accurate information about its three-dimensional shape, size, and location are required. The accuracy with which this information can be recovered can in principle be improved by integrating across extended regions of the visual scene, to incorporate information from objects other than the one that is to be picked up. We used a simple prehension task to investigate whether the presence of another object altered the apparent shape and distance of an object to be grasped. Participants grasped a static binocularly viewed elliptical cylinder, presented alone or in the presence of a second cylinder. This flanking object was either static or rotating, and was viewed either monocularly or binocularly. The presence of the flanking object had a significant effect on both grip apertures and wrist velocities of reaches to the target object. These results demonstrate that, when controlling prehension, observers integrate information across objects, rather than programming their actions on the basis of their view of the target object alone. Such a strategy is optimal, since it makes use of all the available information, and will thus be expected to deliver more accurate and reliable estimates of the shape and location of the target.

[Supported by the Applied Vision Association.]

◆ **Evidence for a two-stage dual-route model of vision for action and perception using the Judd illusion**

A K Dunn, P Thompson¶ (Division of Psychology, School of Social Sciences, Nottingham Trent University, Burton Street, Nottingham NG1 4BU, UK; ¶ Department of Psychology, University of York, Heslington, York YO10 5DD, UK; e-mail: andrew.dunn@ntu.ac.uk)

Milner and Goodale's dual-route hypothesis provides a framework for understanding how visual information is processed for action and perception. However, despite neurological evidence, attempts to demonstrate this division in healthy human brains has yielded mixed results, leading some to argue in favour of a unitary account. We have explored immediate (experiments 1 and 2) and delayed (experiment 3) pointing and perceptual line matching, at the ends and unmarked midpoints of the Judd illusion. The results of these experiments demonstrate that, whilst both pointing and matching are affected by the illusion, the pattern of performance is different across modality: immediate pointing performance is generally less accurate (bigger errors) than line-matching performance; delayed pointing accuracy improved (errors were reduced) while line-matching accuracy remained unchanged. Immediate pointing performance also showed a hemispace asymmetry that was not present in the matching task. We argue that these data do not fit either the unitary or the standard dual-route account, and are best understood in the context of a two-stage dual-route model. We suggest that looking for differences in the pattern of results might serve a more useful approach than focusing on null effects in the motor task.

[Supported by BBSRC.]

◆ Vestibular-evoked hand stabilisation during body motion

J-P Bresciani, E Guillaud¶, M Guerraz§, M Simoneau#, G M Gauthier¶, H H Bühlhoff, J Blouin¶ (Max Planck Institute for Biological Cybernetics, Spemannstrasse 38, D 72076 Tübingen, Germany; ¶ UMR Mouvement & Perception, CNRS et Université de la Méditerranée, 163 avenue de Luminy, F 13288 Marseille Cedex 9, France; § Laboratoire de Psychologie et Neurocognition CNRS UMR 5105, Université de Savoie, F 73376 Le Bourget du Lac, France; # Faculté de Médecine, Division de Kinésiologie, Université Laval, Québec, QC G1K 7P4, Canada; e-mail: bresciani@tuebingen.mpg.de)

Recently, vestibular signals have been shown to contribute to the online control of arm reaching movements. The present experiment had two main goals: (i) measure the latencies of vestibular-evoked arm responses, and (ii) determine whether these responses depend on cognitive processing. Subjects were seated in complete darkness, the right arm raised straight at shoulder level, and were instructed to keep their hand stable in space in spite of unpredictable passive whole body rotations. The EMG latencies of vestibular-evoked arm responses were measured and compared with the EMG latencies of the same muscles when tracking a visual target with the hand. For both tasks, we also tested the influence of pre-cueing on the responses. The main results are: (i) EMG latencies were significantly shorter for vestibular-evoked (162 ms on average) than for visual-based tracking responses (327 ms), and (ii) the influence of pre-cueing on the initial direction of arm responses was very strong in the tracking task (83% of errors in catch trials) and very weak for the vestibular-evoked responses (only 10% of errors in catch trials). These results show that the vestibular control of arm movements has rather short latencies and is virtually independent of cognitive processing.

◆ Effects of sound localisation on postural sway

J A Altman, N I Nikitin (Laboratory of Hearing Physiology, Pavlov Institute of Physiology, Russian Academy of Sciences, nab. Makarova 6, 199034 St Petersburg, Russia; e-mail: altman@infran.ru)

The effect of moving sound in the vertical plane on postural sway was studied during quiet standing in healthy humans. The experiments were conducted in a completely dark anechoic chamber. Noise stimulus was presented through an array of stationary 53 loudspeakers mounted on a semicircular hoop. The array was positioned in the median sagittal plane. The sound stimulus moved front-to-back. The instantaneous centre of foot pressure was recorded with a force platform. The effect of the vertically moving sound could take the form of a reduction of the magnitude of body sway and an alignment of the direction of body sway with the plane of sound motion. A deflection of the body sway was opposite to the direction of moving sound followed by an opposite deflection after cessation of sound stimulation. During sound stimulation the frequency spectrum of the body sway shifts to low frequencies in comparison with the sway in silence. This effect is more expressed in the anterior-posterior direction, ie in the plane of the moving sound. The postural effects of the moving sound are probably due to an attraction of the subjects spatial attention to the sound-source movement.

◆ Cognitive effects on the walk-run transition during locomotion

A Pelah, D P Chambers¶, C d'Arch-Smith¶, J I Cameron§, C-H Lee§, J Lasenby§ (Department of Electronics, University of York, Heslington, York YO10 5DD, UK; ¶ Department of Physiology, Development & Neuroscience, University of Cambridge, Downing Street, Cambridge CB2 3EG, UK; § Department of Engineering, University of Cambridge, Trumpington Street, Cambridge CB2 1PZ, UK; e-mail: ap23@york.ac.uk)

The preferred transition speed (PTS) from walking to running is thought to depend on kinetic, biomechanical, and energetic factors. We considered whether PTS may also be modulated by central cognitive demand or from cues of peripheral origin. Ten subjects walked on a treadmill as speed was increased from 3 to 9 km h⁻¹, in 0.5 km h⁻¹ steps over 5 s, and held constant for a further 15 s at each interval. PTS and lower-body movements were extracted with an active-marker motion-capture system. Five of the subjects repeated the task while responding vocally to a Stroop colour word test flashed on a large screen. The other five repeated it with one ankle dorsiflexed with sports strapping, and then finally with the Stroop condition added. Step length and duration showed no gait asymmetry due to the strapping. Results are expressed in Froude numbers to account for physical differences between subjects. The Stroop condition increased mean transition speeds ($Fr = 0.55$) significantly compared to control ($Fr = 0.47$), while strapping only tended to decrease response ($Fr = 0.38$), or restore response to control levels when combined with Stroop ($Fr = 0.44$). We conclude that central, visually-based cognitive demand can suppress normal triggers for gait transition in competition with demand from the locomotor periphery.

Thursday

LIGHTNESS, BRIGHTNESS, ILLUMINATION**◆ The role of physical contrast in Agostini and Galmonte's reversed-lightness-induction Necker cube**

A C G Galmonte, A Soranzo[¶], T A Agostini (Department of Psychology, Trieste University, via S Anastasio 12, Trieste, I 34134, Italy; [¶] University of Teesside, Borough Road, Middlesbrough, Cleveland TS1 3BA, UK; e-mail: galmonte@units.it)

Agostini and Galmonte (2002 *Psychological Science* **13** 88–92) reported a configuration showing that when grouping factors are optimised, a grey target totally surrounded by black appears darker than an equal grey target totally surrounded by white. The theoretical assumption is that, when higher-level factors act simultaneously with lower-level factors, the former prevails over the latter. Specifically, it is assumed that the lightness induction produced by the global organisation principle of perceptual belongingness prevails over retinal lateral inhibition. The aim of the present study was to test the hypothesis that lightness induction produced by perceptual grouping does depend on the physical contrast between induced and inducing elements. To test this hypothesis, we systematically manipulated, in a number of psychophysics experiments, the relative physical contrast among the regions forming the original Agostini and Galmonte configuration. Observers were asked to match the lightness of both the inducing and induced element on a Munsell scale. We found that lightness induction produced by perceptual organisation principles depends on relative physical contrast between the induced and the inducing elements. Results are interpreted in accordance with previous studies on the relationship between lightness induction and physical contrast. [Supported by MIUR Grant 2005115173.]

◆ Brightness spatiochromatic effect

A D Logvinenko, T Lu, S J Hutchinson (Department of Vision Sciences, Glasgow Caledonian University, Cowcaddens Road, Glasgow G4 0BA, Scotland, UK; e-mail: a.logvinenko@gcal.ac.uk)

Colour of an object depends on its frequency content. When presented against a chromatic background, thin neutral strips get tinged (Logvinenko, 2001 *Perception* **30** 223–232). Surprisingly, their brightness changes too. We measured this effect for three observers. Neutral, horizontal, equally spaced test strips (8, 4, 2.5, and 0.5 cycles deg⁻¹) were presented on equiluminant (25 cd m⁻²) coloured backgrounds (3.2 deg × 5.2 deg). Observers adjusted the colour of the matching bar presented on the neutral (25 cd m⁻²) background below, to that of the illusory colour of the strips; 30 chromaticities of the backgrounds were tested. Three matches were made for each frequency and each background chromaticity. Viewing was binocular. For the low (0.5 cycle deg⁻¹) frequency strips, there was no effect (the luminance of the match was in accord with the luminance of the strips for all the backgrounds). For higher frequencies, the strips on the backgrounds of 'cold' colours looked brighter and those on the background of 'warm' colours darker. The effect gradually increased with the frequency reaching its maximum at 8 cycles deg⁻¹ (up to a factor of 2). Since the strips/background luminance contrast was zero we conclude that brightness is produced by a visual mechanism, the spatiochromatic characteristics of which are different from those of the luminance channel.

[Supported by a research grant from The Wellcome Trust (GR068672MA).]

◆ Processing of luminosity in the visual system: Is luminosity a basic feature?

U Leonards, A Correani[¶], N E Scott-Samuel (Department of Experimental Psychology, University of Bristol, 12A Priory Road, Bristol BS8 1TU, UK; [¶] Department of Psychology, Università di Roma "La Sapienza", via dei Marzi 78, I 00100 Rome, Italy; e-mail: ute.leonards@bristol.ac.uk)

Light-emitting (luminous) objects are perceived as qualitatively different from reflecting objects, and this difference seems to be linked to differential cortical activity for light-emitting and reflecting objects in the occipito-temporal cortex (Leonards et al, 2005 *Cognitive Brain Research* **24** 173–176). However, it is still unclear whether object luminosity is treated as an independent visual feature (a building block of visual perception) comparable to orientation, motion, colour, or even faces. In a series of visual-search experiments, targets perceived as light-emitting amongst perceptually reflecting distractors of similar luminance led to efficient search, while reflecting targets within light-emitting distractors led to inefficient search. However, control experiments revealed that search efficiency for light-emitting targets was induced by the presence of luminance gradients producing the percept of luminosity, rather than by luminosity itself. It appears that the perceptual quality of luminosity does not reach feature status, questioning earlier hypotheses about specific sensory mechanisms to detect light-emitting objects. The role of gradients in visual perception, as yet relatively unexplored, remains to be resolved.

[Supported by the British Academy (SG-38465).]

◆ **Achromatic contrast and assimilation: The role of perceptual organisation**

T A Agostini, A C G Galmonte, G Righi (Department of Psychology, University of Trieste, via San Anastasio 12, I 34134 Trieste, Italy; e-mail: agostini@units.it)

In the visual world, the perceptual features of an object are affected by the context in which that object is perceived. An increase in perceived similarities between the object and its surround is called an assimilation effect, whereas an increase in their perceived differences is called a contrast effect. An account is provided for the role of perceptual organisation in determining whether lightness contrast or assimilation is perceived. Assimilation occurs when the perceptual group is ambiguous or unstable, whereas contrast is perceived in the context of stable perceptual groupings elicited by Gestalt principles of perceptual organisation. By using psychophysical methods, in three experiments it is shown that assimilation occurs when intentional effort is needed to disambiguate among possible perceptual groupings whereas contrast is observed when belongingness is unambiguously and spontaneously perceived.

[Supported by MIUR Grant 2005115173 to the first author.]

◆ **Depth and lightness: Mid-level model tested against high- and low-level models**

A Gilchrist, A Radonjić, D Todorović¶ (Department of Psychology, Rutgers University, 101 Warren Street, Newark, NJ 07102, USA; ¶ Department of Psychology, University of Belgrade, G Kaljubina 18–20, Yu 11000 Belgrade, Serbia; e-mail: alan@psychology.rutgers.edu)

A relaxed coplanar ratio principle is proposed in which the strength of a coplanar ratio is weakened as the target is moved away from its coplanar neighbour laterally, in depth, or in orientation. Evidence is presented from the replication of an experiment by Kardos (1934 *Ding und Schatten* [Object and Shadow] *Zeitschrift für Psychologie* Ergänzungsband 23, translated by D Todorović, edited by A Gilchrist). A target appeared almost white in a far shadowed plane but almost black in a near lighted plane, even though the retinal image was held constant and even though the target was separated from its coplanar neighbour by a gap. In another experiment, a square target of constant luminance was rotated through a series of different orientations under conditions in which the relaxed coplanar-ratio principle predicted the target should become darker while a high-level model in which the direction of the light source is taken into account predicted the target should become lighter. The target became significantly darker. Low-level models of lightness cannot account for depth effects in general. High-level models that take into account light source intensity and direction are not necessary, as the mid-level relaxed coplanar-ratio principle can account for the data better.

[Supported by National Science Foundation: BCS-0236701, Public Health Service: GM 60826-02.]

◆ **Observer ratings for natural scenes under varying illumination: Separating high-level and low-level processes by inversion and a low-level visual-difference predicting model**

P G Lovell, M To¶, D J Tolhurst§, T Troscianko (Department of Experimental Psychology, University of Bristol, 12A Priory Road, Bristol BS8 1TU, UK; ¶ Department of Physiology, Development and Neuroscience, Physiological Laboratory [§ Department of Physiology], University of Cambridge, Downing Street, Cambridge CB2 3EG, UK; e-mail: p.g.lovell@bristol.ac.uk)

We are developing a model which predicts the extent to which two images appear different to a human observer (Párraga et al, 2005 *Vision Research* 45 25–26). The model works by locally comparing the image contrast (luminance plus two chromatic channels), and therefore operates purely on low-level information. However, when people view images, they may ignore certain features of the image which appear unimportant. We hypothesise that image features arising from random changes in illumination may be thus disregarded by humans, but not by the model. Furthermore, we expect that inversion of the image may make it harder to discount such illumination noise, since the light-from-above assumption is violated. Monochrome images may also make it more difficult to discount shadows without full knowledge of scene structure. We examined ratings of differences between pairs of natural scene images taken of the same object as time of day and weather conditions varied, and presented in the following modes: upright, inverted, coloured, and monochrome images, and compared the ratings with the predictions of the image-difference model. We found discrepancies in the predicted direction between the observer and model ratings which indicates that there is a tendency to discount illumination noise when comparing natural images.

◆ **Constancy in motion**

S Zdravković (Odeljenje za Psihologiju, Filozofski Fakultet, Univerzitet u Novom Sadu, Stevana Musica 24, 21000 Novi Sad, Serbia; e-mail: szdravko@f.bg.ac.yu)

Studies of lightness constancy typically involve comparing two objects of the same shade while placed under different illuminations. Here, motion was used in an attempt to stress object identity.

Thursday

A lightness judgment was made for a grey target, which was then seen to move into another illumination level for the second match. The shade was judged significantly lighter when the object was placed under the higher than under the lower illumination ($F_{1,13} = 8.84$, $p = 0.010$). Failure of constancy thus occurs even when object identity is not in question. A priming paradigm was used to assess the strength of constancy: one shade would appear in one illumination level and another shade in the other illumination level. Motion was used to trick observers into thinking that only a single object was presented. The estimated shade varied as a function of the shade of the prime ($F_4 = 5.71$, $p = 0.001$). Finally, observers who were shown the same object in both illuminations were asked to make another match when the object was removed from view, that of its true colour independent of illumination. The value of this match-from-memory was in between the values for the two illumination levels ($F_2 = 5.03$, $p = 0.015$).

◆ **Glare effect animations: A peculiar case of perceptual causality**

D Zavagno, D Bressanelli¶ (Dipartimento di Psicologia, Università di Milano-Bicocca, piazza dell'Ateneo Nuovo 1, I 20126 Milan, Italy; ¶ Department of General Psychology, University of Padua, 8 via Venezia, I 35100 Padua, Italy; e-mail: danielle.zavagno@unimib.it)

We studied a peculiar case of perceptual causality in animated-glare-effect displays. The starting point of the animations consisted of a white background (B) on which a central white square (T) was flanked by four black squares (F). During one full sequence, the luminances of T and B were kept constant, while the luminance of F varied progressively in time and space from F-in to F-out, generating incremental linear gradients that increased smoothly until F-in = T, at which point the process inverted until F was completely black again. With an animation of 20 frames s^{-1} , observers reported that the brightness modulations of F were due to the variations in the luminous flux of T, while it was actually that the luminance modulations of F were causing the phenomenal brightening of T. We studied this type of perceptual causality by employing four animations with different temporal parameters for F (5, 20, 50, 100 frames s^{-1}). Participants were asked to decide, using a forced-choice paradigm, whether the brightness modulations of F were caused by T. Data showed clear perceptual dependence of the brightness of F on T, except for 5 frames s^{-1} animation, in which the causal dependence of F from T appeared clearly only towards the end of the ascending sequences.

SEEING 3-D: SURFACE, SHAPE, SPACE, MOTION

◆ **Activation of competing perceptual assumptions for 3-D shape**

Q Zaidi, X Meng (SUNY College of Optometry, 33 West 42nd Street, New York, NY 10036, USA; e-mail: qz@sunyopt.edu)

To decode 2-D retinal motion into 3-D shape, the visual system has to use perceptual assumptions like surface rigidity and motion parallax. If two assumptions lead to incompatible percepts, what factors lead to the activation of one assumption versus the other? We rotated one cycle of a textured vertical sinusoidal corrugation around the horizontal axis through the zero-crossings. The main optic flow is then a horizontal gradient of vertical velocities: maxima in opposite directions at peak and trough, and minima at zero-crossings. With central fixation, observers perceive a grossly non-rigid surface of two convexities rotating in opposite directions, consistent with a parallax assumption that assigns relative depth inversely proportional to relative velocity. With fixation on a velocity maximum, the perceived curvature of the fixated half-cycle increases, while the curvature of the farther half-cycle decreases till the percept changes to that of a rigidly rotating sinusoid. The perceived convexity is always at the fixation half-cycle irrespective of the veridical phase. We showed that the rigidity assumption is activated when the sensitivity to velocity gradients decreases with retinal eccentricity so that motion parallax does not support an unambiguous 3-D percept. Moreover, textures that promote smooth surface percepts are more likely to activate rigidity assumptions.

[Supported by NEI grants EY07556 and EY13312.]

◆ **A new paradigm for 3-D shape perception**

Z Pizlo, Y Li, R M Steinman¶ (Department of Psychological Sciences, Purdue University, 703 Third Street, West Lafayette, IN 47907-2081, USA; ¶ Department of Psychology, University of Maryland at College Park, College Park, MD 20742-4411, USA; e-mail: pizlo@psych.purdue.edu)

The last 25 years of research on 3-D shape perception have been dominated by 'Marr's paradigm'. This paradigm makes two key assumptions: (i) perceived 3-D shape is derived from depth relations represented in a viewer-centred coordinate system (called the 2.5-D sketch), and (ii) the 2-D shape on the retina, which is a perspective image of a 3-D object, does not provide useful

information, implying that figure-ground organisation is not used for 3-D shape perception. A review of our recent experiments shows that these two assumptions must be rejected. The paradigm introduced by Marr must be changed. Our new paradigm makes the following assumptions: (a) perceived 3-D shape is derived from 2-D retinal shape, (b) figure-ground organisation is critical: it establishes the 2-D shapes on the retina, and (c) 3-D metric properties of the shape perceived, missing from the 2-D retinal shape, are produced by applying shape constraints, not by reconstructing depth relations. Shape constraints include the symmetry and compactness of the 3-D object. 3-D reconstructions, based on our new model, are consistent with subjects' 3-D percepts.

◆ **An in-depth look into 3-D: A comparative approach to stereokinetic effects**

E Clara, L Regolin, M Zanforlin, L J Rogers¶, G Vallortigara§ (Department of General Psychology, University of Padua, via Venezia 8, I 35131 Padua, Italy; ¶ Centre for Neuroscience and Animal Behaviour, University of New England, Armidale, NSW 2351, Australia; § Department of Psychology and BRAIN Center for Neuroscience, University of Trieste, via San Anastasio 12, I 34123 Trieste, Italy; e-mail: elena.clara@unipd.it)

The human visual system shows striking abilities to extract 3-D shape information from 2-D image transformations. An example of structure-from-motion perception is the stereokinetic effect: perception of a 3-D solid object following frontoparallel rotation of certain 2-D stimuli. Our aim was ascertaining whether non-human species could at all perceive stereokinetic illusions, as this had not been investigated before in species other than our own. Animal models, moreover, offer the opportunity to investigate whether this phenomenon occurs even in the absence of any previous visual experience with these stimuli. Adult common marmosets (*Callithrix jacchus*) and newborn visually naive chicks (*Gallus gallus*) were trained by using, respectively, conditioning techniques and filial imprinting. At test, subjects were presented with the choice between two objects, one of which corresponded to a visual transformation (2-D to 3-D or vice versa) of the previously learned one. Both species chose to significantly approach the correct stimulus. These data suggest that the basic mechanisms involved in structure-from-motion extraction, at least in the case of stereokinetic effects, are available to naive newborn animals, and are shared by the avian and mammalian nervous systems, suggesting either basic homology between the two vertebrate classes or convergent evolution to cope with similar evolutionary pressures.

◆ **The relationship between apparent illumination and lightness in 3-D scene**

G Menshikova (Laboratory of Perception, Department of Psychology, Moscow State University, 11-5 Mokhovaya, 125009 Moscow, Russia; e-mail: MGJa@rambler.ru)

According to the albedo hypothesis, apparent illumination and lightness are coupled in the visual image and their cooperation depends on the interpretation of the complete scene. One way to change the relationship between their values is to alter the apparent slants of surfaces of a scene without changing the retinal image (Gilchrist, 1977 *Science* **195** 185–187). In this laboratory, we investigated the influence of apparent slant of a surface on the lightness estimation using Benary illusion. In our experiment a scene containing two intersecting surfaces with different slants and differently illuminated was arranged. Benary illusion pattern was attached on both surfaces. Using a pseudoscopic technique we inversed the apparent depth of surfaces. Observers were asked to choose from the Munsell neutral scale the patch matching gray Benary triangles in lightness. The magnitude of the Benary illusion was measured for direct and inversed orientation of surfaces. The results showed that the change in the magnitude of the Benary illusion could be explained in accordance with the albedo hypothesis.

[Supported by Russian Foundation for Basic Research grant 06-06-80390a.]

◆ **3-D volumetric object perception from the dynamic pantomime effect**

Q Zhang, K Mogi, M Idesawa¶ (Sony Computer Science Laboratories Inc., Takanawa Muse Building, 3-14-13, Higashigotanda, Shinagawa-ku, Tokyo 141-0022 Japan; ¶ Graduate School of Information Systems, University of Electro-Communications, 1-5-1 Chofugaoka, Chofu-shi, Tokyo 182-8585, Japan; e-mail: zhangq@csl.sony.co.jp)

Shape-from-motion is an issue which has been studied for a long time. Usually it refers to the 3-D perception from 2-D stimuli, and some researchers have investigated the brain areas involved in inferring 3-D shape from 2-D motion cues (Murray et al, 2003 *Cerebral Cortex* **13** 508–516; Peuskens et al, 2004 *Journal of Cognitive Neuroscience* **16** 665–682). On the other hand, a visual phenomenon named the pantomime effect has been reported (Zhang et al, 1998 *Japanese Journal of Applied Physics* **37** L329–L332), in which an illusory 3-D volumetric object is perceived with binocular viewing owing to some stereoscopically displayed inducing objects. Here, we report the dynamic perception where the 3-D volumetric objects are perceived to change their shapes continuously as a result of the motion of the inducing objects. This is a kind of volume perception

Thursday

in object-from-motion, and is a 3-D version of the shape-from-motion. We conducted fMRI experiments to measure the brain activities involved in this perception, and compared them with that induced by the static pantomime effect. Our experimental results suggest the existence of a coordinated system of brain areas, including the occipital visual cortex, parietal somatosensory cortex, frontal motor/premotor cortex, prefrontal biological intelligence cortex, and temporal language areas.

◆ **Neural correlates of the perception of coherent motion-in-depth and self-motion as measured by fMRI**

M Raabe, F Acs, R M Rutschmann, M W Greenlee (Institute for Experimental Psychology, University of Regensburg, Universitätsstrasse 31, D 93053 Regensburg, Germany; e-mail: markus.raabe@psychologie.uni-regensburg.de)

Several studies have investigated fMRI during the perception of random-dot kinematograms (RDKs), but only one has compared the visually induced sensation of self motion (vection; Kleinschmidt et al, 2002 *NeuroImage* 16 873–882). We sought to define 3-D RDK stimuli using standard 3-D graphics that reliably induced vection. During fast fMRI (TR = 1, $B_0 = 3$ T) we presented subjects coherently animated in-plane translating (A), in-depth expanding/contracting (B) RDKs, as well as a combination of these motion types (C). Each RDK was presented for 40 s, during which time the dot motion cycled repetitively through expansion/contraction or through frontopolar translation. Subjects were instructed to press a button when they felt themselves moving in space (vection). In C subjects reported a pronounced sense of 3-D curvilinear vection. Contrasting C with A and B yields activated clusters in visual and dorsal parietal areas (PPC). Applying Granger causality mapping on the activated brain regions indicates effective connectivity from V5 to PPC predominantly in C. Moreover, we found a deactivation in a small region in the insular cortex, which apparently processes vestibular information. This pattern of activations/deactivations could reflect the neural processing related to the differentiation between object and self motion.

[Supported by a grant from the European Union (EU IST Cognitive Systems, project 027198) to MWG.]

◆ **Object constancy and self-motion**

M Wexler (LPPA/CNRS, College de France, 11 place Marcelin Berthelot, F 75005 Paris, France; e-mail: wexler@ccr.jussieu.fr)

It is generally assumed that size and shape constancies are the outcomes of a series of computations that have retinal input, and only retinal input, as their starting point. If so, then object constancy should be identical as long as relative motion between the object and the observer is held fixed: object constancy should be as strong for object motion as for equal-and-opposite observer self-motion. This is also generally assumed to be true, despite some possible recent evidence to the contrary arising from the Pinna illusion. Here I show that both size and shape constancy are weaker for object motion than for observer self-motion. The experiments rely on tasks in which subjects report changes in the proximal dimensions: to the extent that subjects can precisely report these changes, one can conclude that they do not have the constancy in question. Subjects performed these tasks in conditions of self-motion (tracked head movement with respect to a stationary object) and object motion, in which relative movement from a self-motion trial was 'played back' to an immobile subject. Responses in self-motion trials were less precise than in object motion trials, providing evidence that size and shape constancies are stronger during observer self-motion.

◆ **The effect of rigid and non-rigid motion on object recognition**

F N Newell, A Setti¶ (School of Psychology and Institute of Neuroscience, Trinity College Dublin, Dublin 2, Ireland; ¶ Department of Psychology, University of Bologna, Bologna, Italy; e-mail: fiona.newell@tcd.ie)

It is known that motion is an important cue for object recognition, but our understanding of what motion information is integrated into an object's representation in memory is poor. We investigated the role of rigid body and non-rigid, part motion on object recognition using a priming paradigm. Participants were trained to categorise four unfamiliar target objects, each defined as a unique combination of shape and motion patterns. During testing, static images of target objects were primed with objects of either (a) the same body and parts motion; (b) the same body but different parts motion; (c) a different body but same part motion, or (d) no body or part motion (ie static). In experiment 1 we found facilitation for same body motion but not same part motion as the target. When the motion was perceived as causal, then it facilitated recognition (experiment 2). Object motion facilitated recognition even when the motion

was not a reliable indicator of object identity (experiment 3). Our results suggest that both rigid and non-rigid object motion are important for object recognition even when shape information is fully available. These findings have important implications for our understanding of the role of dynamic information in object memory.

POSTER SESSION

COLOUR SPACE: ITS STRUCTURE AND BIOLOGICAL BASIS

◆ Colour-space distortion in women who are heterozygous for colour deficiency

D L Bimler, J Kirkland (Department of Human Development, Massey University,

Private Bag 11-222, Palmerston North, New Zealand; e-mail: pushkin@paradise.net.nz)

Women with a single copy of an aberrant photopigment gene display nearly normal colour vision with only subtle departures from normality. On the basis of judgments of colour similarity, we constructed personal colour spaces for a group of twelve heterozygous women—relatives of colour-deficient males—for comparison with age-matched controls. To collect subjective similarities, colour stimuli were presented in groups of three while subjects picked the odd-one-out from each triad. Seventy-five triadic combinations of sixteen stimuli were each printed on a separate card. These stimuli were spaced at intervals around the hue circle, with two levels of lightness and two levels of saturation; they approximate the Munsell papers used in the D15 panel test. Judgments were analysed with multidimensional scaling (MDS), summarising them as one consensus colour space for the heterozygotes and another for the controls. Individual-differences MDS was also applied, resulting in a single colour space which can be adjusted to fit each subject's responses individually by compressing it along its axes. Subjects are characterised by their axial-compression parameters. Heterozygous women showed a trend towards colour-space compression in a red–green dimension, or reduced salience of that dimension compared to controls, though less extreme than found in overt colour deficiency.

◆ Gender differences in weighting the dimensions of colour space: Do males neglect red – green differences?

D L Bimler, L Harper¶, F Duffie¶, V Bonnardel§ (Department of Human Development, Massey University, Private Bag 11-222, Palmerston North, New Zealand; ¶ Division of Psychology [§ Reg Vardy Building, Saint Peter's Campus], University of Sunderland, Sunderland SR6 0DD, UK; e-mail: pushkin@paradise.net.nz)

A recent study (Bimler et al, 2004 *Color Research & Application* 29 128–134) revealed a small group difference in the salience of colour-space dimensions between males and females, as shown in their judgments of colour similarity. Fifty young adults (25 males, 25 females) took part in an attempt to replicate that finding. Stimuli were 21 Munsell samples of equal lightness, at equal steps around the hue circle, at the highest chroma available. These were presented in groups of three, while subjects indicated the least similar hue or 'odd-one-out' from each triad. A balanced incomplete design of 70 triads ensured that each hue was presented the same number of times, in a different context each time. Consensus analysis of the similarity judgments revealed that all subjects approached a common consensus, apart from one male, whose data were removed. The remaining males were 'noisier' than the females, with more deviations from the consensus. Analysis with multidimensional scaling (MDS) confirmed that any difference between separate male and female colour spaces was minor, with the expected hue circle in both solutions. However, individual differences revealed by MDS replicated the earlier study by finding a significant difference between the male and female groups, with the former placing slightly lower weight on a red–green colour-space dimension.

◆ Colour space distortions in patients with mercury vapour intoxication

C Feitosa-Santana, G V Paramei¶, D L Bimler§, M F Costa, M Lago, N N Oiwa, D F Ventura (Núcleo de Neurociências e Comportamento, Departamento de Psicologia Experimental, Instituto de Psicologia, Universidade de São Paulo, avenida Prof. Mello Moraes 1721, Bloco A, Sala D9, Cidade Universitária, 05508.900 São Paulo, SP, Brasil; ¶ Institute of Psychology, Darmstadt University of Technology, Alexanderstrasse 10, D 64283 Darmstadt, Germany; § Department of Health and Human Development, Massey University, Palmerston North, New Zealand; e-mail: claudia@feitosa-santana.com)

Colour vision was examined in patients with mercury (Hg) vapour intoxication. We assessed the type and degree of distortions of individual colour spaces. Hg patients ($N = 18$; 42.1 to 6.5 years; exposure time from 10.4 to 5.0 years; time away from exposure from 6.8 to 4.6 years) and age-matched controls ($N = 18$; 46.1 to 8.4 years) were subjected to the D-15 and the D-15d tests. In addition, subsets of caps were employed in a triadic procedure. Matrices of inter-cap subjective

Thursday

dissimilarities were estimated from each subject's 'odd-one-out' choices, and processed by non-metric multidimensional scaling. 2-D colour spaces, individual and group, were reconstructed with the axis interpreted as the red–green (RG) and blue–yellow (BY) dimensions. In the traditional procedure, the patients results were significantly different from controls in the D-15d test ($p = 0.0003$). The losses were concentrated in the BY axis. In the colour space analysis, colour configurations were compressed along both dimensions and the residuals were calculated in comparison to controls: 0.10 (RG) and 0.19 (BY). The losses were classified as diffuse, suggesting that this method could be more sensitive. The present findings agree with earlier studies demonstrating that colour vision is impaired in patients with long-term Hg intoxication, suggesting that intoxication may not be totally reversible.

[Supported by FAPESP, Capes, CNPq.]

◆ **Basic quantities of colour photometry**

L L Polosin (Baltic State Technical University (BSTU), 1-ya Krasnoarmeyskaya 1/21, 198005 St Petersburg, Russia; e-mail: polosin39@mail.ru)

There is not yet a final solution how colour can be quantitatively represented in a metric vector space. The difficulty lies in the determination of the fundamental quantities. Standard visual photometric quantities, adopted by the International Lighting Vocabulary of Commission Internationale de l'Éclairage (CIE 1970), are based on the use of the spectral luminous efficiency function $V(\lambda)$. They do not specify colours. In colorimetry, colour is specified numerically as a physically defined visual stimulus in a non-metric vector space. I propose a new metric vector space and colour photometry based on the responses of visual colour channels, metric vector colour space, and multi-stage colour-opponent transformation of the responses. A model of colour vision is proposed. It is shown that colour responses are vectors in metric space. This space is uniform and is subject to scalar multiplication. The basic law of colour photometry is vector additivity. According to the proposed model, the fundamental quantities of colour photometry are colour-response amplitude and angles between colour vectors: heterochromatic brightness depends on colour-response amplitude; hue and saturation of colour depend on angles.

◆ **Spherical colour space with Riemann geometry**

Y P Leonov, E N Sokolov ¶ (Department of Higher Mathematics, State Technical University [STU], Leningradskii pr. 64, 125319 Moscow, Russia; ¶ Department of Psychophysiology, Moscow State University [MGU], Mokhovaya 11/5, 125009 Moscow, Russia; e-mail: yleo@aha.ru)

Colour can be measured in terms of the linear colour space (LS) proposed by T Young. LS provides high resolution, but its geometry does not allow us to measure colour differences—the distance between colour points in LS is not equal to the magnitude of difference perceived by an observer. Colour scaling experiments by Sokolov suggest that real colours are located on the surface of a hypersphere in a four-dimensional space. Observed colour differences were empirically defined as the Euclidean distance between points on the surface of the hypersphere. We introduce here a colour space on the surface of a four-dimensional hypersphere. The structure of the space is determined by the three coordinates R, G, B of LS, and an additional coordinate Q representing response of the retina to darkness. The new colour space is spherical. It remains three-dimensional, but its geometry becomes Riemannian, which differs from the geometries used by Helmholtz and Schrödinger. The main advantage of the new approach is that it makes it possible to formally define colour differences as the Euclidean distance between colour points. Furthermore, the spherical colour space includes a significantly wider range of perceived colours than LS.

◆ **Comparing chromatic detection ellipses of colour-deficient subjects with standard colour vision tests**

E Dischler, A Valberg (Department of Biophysics, Institute of Physics, Norwegian University of Science and Technology, N 7491 Trondheim, Norway; e-mail: arne.valberg@phys.ntnu.no)

Colour vision tests are not always consistent in their identification of colour vision deficiencies. In thirteen subjects with different degrees of red–green colour vision deficiency we have compared chromatic detection data with the performance on standard colour vision tests. Protan and deutan deficiencies were easily defined by the orientation of the long axes of the detection ellipses, and plots of cone contrast thresholds showed clear elongations along either the L- or the M-cone axis. However, in several cases this classification did not correspond to that made by standard tests. The Ishihara test correctly identified all thirteen colour defective subjects, but only four of the nine deutan subjects were correctly classified as deutans. Furthermore, Ishihara indicated a deutan deficiency for all four tested protans. The interpretation of the Farnsworth 100 hue test was not straightforward; in some cases the correct type of deficiency was not identified.

We also found an unexpected lack of correlation between the parameters of the ellipses and the error scores of the Farnsworth 100 hue test. The Farnsworth D15 and H16 tests were superior to the other tests, and, except in one case, a combination of these two tests identified all subjects correctly as protan or deutan.

◆ **Gender differences in colour preference: Men are more predictable than women**

V Bonnardel, L Harper, F Duffie, D L Bimler¶ (Division of Psychology, University of Sunderland, Reg Vardy Building, Saint Peter's Campus, Sunderland SR6 0DD, UK;

¶ Department of Human Development, Massey University, Private bag 11-222, Palmerston North, New Zealand; e-mail: valerie.bonnardel@sunderland.ac.uk)

Gender differences in colour preference are consistently observed from infancy through adulthood (Hurlbert et al, 2003 *Perception* 32 Supplement, 129b) to old age. To characterise these differences, colour preference judgments were collected from fifty young adults (twenty-five females, twenty-five males) and subjected to consensus analysis (CA), multidimensional scaling (MDS), and multivariate regression. Stimuli were 21 Munsell samples of constant lightness (value 8), at equal steps around the hue circle with the highest chroma available. These were presented three at a time, while subjects indicated their preferred colour from each triad. The preference rankings of men could be summarised by a MDS solution with two dimensions identified as hue (from red to blue) and chroma. Linear combinations of these variables account for the preferences of twenty-four men and only fifteen women. CA confirms that the consensus pattern of men is different from that of women, while the agreement among women (44%) is lower than among men (63%). A MDS solution for 'subject space' segregates men and women almost entirely. These results confirm a dissociation between men and women colour preferences, and suggests a more complex basis for women preferences.

CROWDING

◆ **Features, conjunctions, and crowding effect**

E Pöder (Department of Psychology, University of Tartu, Tiigi 78, EE 50410 Tartu, Estonia; e-mail: endel.poder@ut.ee)

Usually, crowding has been studied with letters or numerals as stimuli. Relevant visual features of these objects are complex and largely unknown. In other studies, with simple stimuli, typically a single visual feature has been varied. In this study, Gabor patches have been used as the target and distractor stimuli. The stimuli differed in three dimensions: spatial frequency, orientation, and colour. A group of 3, 5, or 7 objects was presented briefly in the periphery of the visual field (in random positions around the fixation, eccentricity about 4°). The observers' task was to identify the target—an object located in the centre of a group. A very strong effect of the number of distractors was observed (eg 6 distractors impaired the perception of a target much more severely than 2 distractors). This seems to contradict some earlier studies with different stimuli. With 2 and 4 distractors, bottom-up salience had a remarkable effect—a target was identified easier when it differed from the distractors of a given trial on any dimension. Incorrect responses were frequently selected from the presented distractors, implying a correct conjoning of visual features, though in a wrong position.

◆ **View-point aftereffect of faces is affected by crowding**

M Ahsan, M Sanayei¶ (Neuroscience Group, School of Medicine, Isfahan University of Medical Sciences, Isfahan, Iran [¶ also School of Cognitive Sciences, Institute for Studies in Theoretical Physics and Mathematics (IPM), Tehran, Iran]; e-mail: ahsan@edc.mui.ac.ir)

Previous studies have shown that there are neurons representing specific views of objects in the human visual cortex. After adaptation to an object, the perceived viewing direction of subsequent objects are shifted repulsively from the adapted viewpoint; eg following adaptation by one side-view of a face, the front view is perceived as tilting toward the opposite direction from the adapting side view (view-point aftereffect). We tried to investigate whether flanking of the face adapter with other faces (crowding) has any effect on the view-point aftereffect. We adapted subjects to front and profile faces and measured the magnitude of repulsive shift in perceived direction of faces ranging between front and profile. At the next step we added four other faces as crowders and measured this shift in three different conditions of target-crowder distance. We showed that the magnitude of view-point aftereffect is significantly larger in the presence of the crowders ($p < 0.05$ and paired t -test). We found that the crowder not only does not reduce the adaptation effect but also magnifies it. But this effect fades away when crowders become closer to the target adapter. Our result suggests the existence of competitive interactions between neurons representing different views of faces in the cortex.

[Supported by the Talented Student Office, Medical Education Development Center, Isfahan University of Medical Science.]

Thursday

◆ Differential feature crowding

R van den Berg ¶§, A Hannus§#‡, H Bekkering#, J B T M Roerdink¶§, F W Cornelissen ◆ (¶ Institute for Mathematics and Computing Science, University of Groningen, PO Box 800, NL 9700 AV Groningen, The Netherlands; § School of Behavioral and Cognitive Neurosciences, PO Box 196, NL 9700 AD Groningen, The Netherlands; # Nijmegen Institute for Cognition and Information, University of Nijmegen, Montessorilaan 3, NL 6525 HR Nijmegen, The Netherlands; ‡ Estonian Centre of Behavioural and Health Sciences, University of Tartu, Tiigi 78, EE 50410 Tartu, Estonia; ◆ Laboratory for Experimental Ophthalmology, BCN Neuro-imaging Center, School of Behavioural and Cognitive Neurosciences, University Medical Center Groningen, PO Box 30001, NL 9700 RB Groningen, The Netherlands; e-mail: r.van.den.berg@rug.nl)

Perception of an item is impaired when surrounded by other items, a phenomenon called crowding. Although extensively studied for letters, little is known about crowding in more basic features. We studied this using a number of visual search tasks. In a first experiment, subjects first searched for a colour-, size- or orientation-defined target among twelve identical distractors and the target-distractor contrast for 70% correct performance was determined for each feature. Next, subjects performed conjunction searches (colour + orientation, colour + size) with items presented at these saliency-matched contrasts. Now distractors were heterogeneous, in both feature dimensions. We found that while colour performance was as good in conjunction search as in single feature search, size and orientation performance decreased ($\sim 10\%$ and $\sim 40\%$, respectively). For a second experiment, single feature search displays were generated that consisted of a target among 49 randomly positioned distractors. Items were heterogeneous in the search dimension (10 possible values per feature) and identical in all other feature dimensions. Saliency was again comparable across feature dimensions. We found that orientation search performance was substantially, and size search performance slightly reduced compared to colour search performance. Our results indicate that crowding effects are strong for orientation, small for size and absent for colour.

VISION AND GRAVITY

◆ A study of visual, vestibular, and proprioceptive interaction during exposure of humans to lateral and longitudinal – lateral accelerations

O Vorobyov, I V Bukhtiyarov ¶, M N Khomenko ¶ (Russian Federation State Research, Experimental Institute for Military Medicine of the Ministry of Defence [¶ Ministry of Defence], 12A Petrovsko-Razumovskaya alleya, 125083 Moscow, Russia; e-mail: L.Kornilova@wizards.pp.ru)

It is known that illusions due to exposure to gravitoinertial forces (the force of gravity plus acceleration) can markedly impair the process of spatial orientation in a pilot of a modern or prospective highly maneuverable airplane. A study was performed on six healthy male volunteers aged 19 to 28 years who were exposed, during centrifugation, to lateral + G_y and longitudinal – lateral + G_z / + G_y accelerations. A specially developed technique for determination by the subject of a subjective psychometric vertical was employed. The studies were performed under the following conditions to which the subjects were exposed in the cockpit during rotation of the centrifuge: (i) binocular vision, arms on the arms of the chair (control, baseline conditions); (ii) monocular right-eye vision, arms on the arms of the chair; (iii) binocular vision, hands on knees; (iv) eyes covered by a band, hands on knees. Analysis of the data obtained demonstrated that, during exposure to lateral + G_y and longitudinal – lateral + G_z / + G_y accelerations in subjects with 'a preferably visual modality' of perception of the spatial position, one should anticipate a high probability of a disturbed spatial orientation in cases of absent visual reference points.

◆ Visual pursuit in individuals with various types of dizziness

L N Kornilova, V I Dotsenko ¶, A D Solovieva ¶, V V Temnikova ¶ (Department of Vestibular Research, RF State Research Center—Institute for Biomedical Problems of the Russian Academy of Sciences, 76A Khoroshevskoe shosse, 123007 Moscow, Russia [¶ also I M Sechenov MMA, the MSF 'Statokin', Moscow]; e-mail: L.Kornilova@wizards.pp.ru)

At present, special methods and polyfunctional portable hardware/software complexes are needed for the study, under clinical and simulated conditions, of spontaneous and induced oculomotor responses with visual noise leading to spontaneous and induced illusions and sensorimotor disturbances. For these purposes, a hardware/software 'OCULOSTIM' complex was created, along with computerised tests which allow selective polymodal separate and combined stimulation of visual and vestibular inputs. The subjects were two groups of patients complaining of dizziness. Group 1 were patients ($N = 13$) with consequences of disturbed cerebral circulation and a serious cerebral trauma. Group 2 ($N = 12$) were individuals with clinically recorded psychogenic CNS diseases. An improvement of characteristics of visual pursuit with additional visual stimuli represented as retinal optokinetic stimulation (ROKS) was noted in patients of group 2. In patients

of group 1 during ROKS there was complete annihilation of the eye-pursuit function. A decrease of velocity of slow pursuit and gain in tracking optomotor reactions in the group with organic CNS disease during ROKS indicates a prognostic significance of computerised tests and the possibility of differential diagnostics in neurological patients with organic and psychogenic CNS disease, with the help of an 'OCULOSTIM' hardware/software complex.

- ◆ **Aiming in sport shooting: An interaction between visual and somatosensory systems**
D A Napalkov, M Kolikoff¶, P Ratmanova, V V Shulgovsky (Department of Higher Nervous Activity, Faculty of Biology, Lomonosov Moscow State University, 119992 Moscow, Leninskie Gory, Russia; ¶ Russian State University of Physical Education, Moscow, Russia;
e-mail: napalkov@protein.bio.msu.ru)

We studied the interaction between sensory systems in the pre-shooting period in eleven novice and eight expert pistol shooters. Twelve channels of electroencephalograms, electrocardiograms, and stabilograms were recorded during the rest, shooting, and after the shooting. The postural stability in novice shooters was significantly lower than in experienced ones. Occipital and temporal EEG alpha power was found to decrease significantly during aiming compared to the rest in novice shooters. This is connected with increase of visual attention to the target and the pistol. In expert shooters (but not in novice shooters) a significant increase of R-R intervals took place just before the shooting. According to the Lacey's theory, this could be connected with an increase of attention. But in expert shooters we found that during aiming the alpha power was not less than at rest, or even exceeded the rest level in some expert subjects. This indicates that the visual attention was not very activated during the process. We conclude that in expert shooters high postural stability and good shooting results are achieved by a shift from visual attention to somatosensory one.

COLOUR: OPTICS AND RETINA

- ◆ **ERG responses to colour stimuli: Comparative study of b- and d-wave intensity-response functions in turtle**

P N Kупenova, L A Vitanova, E B Popova, L L Mitova (Department of Physiology, Medical University Sofia, 1 G Sofiiski Street, BG 1431 Sofia, Bulgaria; e-mail: pkupenova@abv.bg)

ERG responses to colour stimuli (450, 520, 550, 568, 620, and 650 nm) have been studied in a wide range (7 log units) of stimulus intensities (I) in dark- and light-adapted eyecup preparations of the turtle (*Emys orbicularis*). Smooth approximation of the response vs intensity functions of the ERG b- and d-wave (ON- and OFF-responses) was carried out and the gain and the contrast gain of the responses were estimated as derivatives of $V(I)$ and $V(\log I)$ functions. The position of the response vs intensity curves along the intensity axis, their steepness and amplitude range depended in a specific manner on the spectral composition of the light. On varying stimulus wavelength, the changes of the b-wave $V(I)$ and the $V(\log I)$ functions were more pronounced than those of the d-wave. So the ON-/OFF-response gain and contrast gain ratios depend not only on I , but on the spectral composition of the light as well. On the basis of the effects of GABA-ergic blockade by picrotoxin it is shown that the GABA-ergic system contributes to the colour-dependent ON/OFF asymmetry.

- ◆ **Compensation effects associated with prereceptoral screening by macular pigment**

B R Hammond Jr, J Stringham, B R Wooten¶ (Vision Sciences Laboratory, Department of Psychology, University of Georgia, Athens, GA 30602, USA; ¶ Department of Psychology, Brown University, Box 1853, 89 Waterman Street, Providence, RI 02912, USA;
e-mail: bhammond@egon.psy.uga.edu)

Macular pigment (MP), a yellowish filter found in the inner retinal layers, is probably one of the most variable features of the human fovea (ranging as high as 1.6 optical density in the foveola to nearly zero by 4° – 5° eccentricity). To study how the visual system compensates for this dramatic and uneven filtering by MP we assessed sixteen subjects (age 24–40 years) with a wide range of MP density. Increment thresholds were measured at 440 and 500 nm at 0° and 6° – 7° eccentricity, using conditions chosen to isolate the π -1 mechanism. For six of the subjects, increment thresholds were also obtained at 1° , 1.75° , and 3° . Yellow (575 nm)–blue (440 nm) and red (600 nm)–green (501 nm) cancellation functions were obtained for these same subjects at the same eccentricities. Despite MP optical densities ranging from 0.02–1.0, hue cancellation values for the Y–B system and π -1 sensitivity did not change across the retina. In contrast, R–G sensitivity changed as a direct function of MP absorbance. Taken together, these results suggest that the visual system compensates for MP density by increasing gain to the S-cone system (the blue lobe of the Y–B system) but not the R–G system.

[Supported in part by grant NSF0350992.]

Thursday

◆ **Immunocytochemical study of AMPA and kainate ionotropic glutamate receptors and mGluR6 metabotropic glutamate receptor in the retinae of lower vertebrates**

L A Vitanova (Department of Physiology, Medical University, BG 1431 Sofia, Bulgaria; e-mail: lilyvita@abv.bg)

Glutamate is one of the main neurotransmitters in the retina. Photoreceptors, bipolar cells, and ganglion cells all use glutamate as neurotransmitter. Glutamate exerts its effects by ionotropic (AMPA, kainate, and NMDA receptors) and metabotropic receptors. The aim of the present work was to study immunocytochemically the AMPA and kainate ionotropic receptors, as well as the metabotropic mGlu6 receptor in frog and turtle retinae. More than 15 different antibodies, directed against the AMPA receptor subunits GluR1, GluR2, GluR2/3, GluR4 and the kainate receptor subunits GluR5, GluR6, GluR6/7, GluR7, KA2, and delta1/2, as well as against the metabotropic mGluR6 subunit were used. The retinae were stained by indirect immunofluorescent method and viewed by light microscopy. The results obtained show that the ionotropic receptors GluR2/3, GluR6/7, KA2, and delta1/2 are widely distributed in the studied retinae. They were localised to brightly fluorescent puncta, a sign for synaptic localisation, in the inner and outer plexiform layers. Some cell bodies were also stained. In frog retina the GluR4 was localised in the Müller glial cells. The mGluR6 receptor was expressed on the dendrites of the ON bipolar cells. The significance of the receptors studied for the synaptic transmission and neuron–glia interactions in the retina is discussed.

◆ **Cone photopigment absorption assessed from retinal afterimage**

K Sakata (Department of Science of Art, Joshibi University, 1900 Asamizodai, Sagami-hara, Kanagawa 228-8538, Japan; e-mail: sakata@joshibi.ac.jp)

Although previous studies have suggested that the colours of retinal afterimages depend on the bleaching of cone photopigments, few reports reveal the mechanisms of cone bleaching, owing to difficulties of measurement. In this presentation, mechanisms of cone bleaching are taken into account by a blank rotation method, which allows exact measurements of the colours of retinal afterimages. The measurements showed that the colour of retinal afterimages depends on three cone mechanisms. However, some of the data were difficult to fit if only cone bleaching was taken into account. These data may show the effect of non-retinal, higher mechanisms.

◆ **Colour perception in patients with pseudophakic eye**

G Chichua, A Chichua, M Pirtskhalaishvili, M Tolmacheva, K Parkosadze¶, A Kezeli¶
(First Hospital of Tbilisi, Eye Disease Clinic 'MZERA', Tsinandali 9, 0144 Tbilisi, Georgia;
¶Laboratory of Vision Physiology, I Beritashvili Institute of Physiology, Georgian Academy of Sciences, Gotua 14, 0160 Tbilisi, Georgia; e-mail: giochi@gmx.net)

As is known, the spectral characteristics of human's normal crystalline lens and artificial PMMA lens differ from each other. As a result, spectral sensitivity of pseudophakic eye might differ from a normal one. Changes of the spectral-sensitivity functions (SSF) were investigated in sixty-six patients (aged 18–73 years; average age: 61 years) with pseudophakic eye. All of them underwent an extracapsular cataract extraction with a PMMA lens implantation. We examined colour vision sensitivity using Farnsworth–Munsell 15-hue test and Lanthony's desaturated 15-hue test. The measurements were taken before the surgical intervention, and 1 and 3 months after the surgery. As expected, the investigation of colour vision in eyes with intraocular lens demonstrated that in the early postoperative period—after 1 month—shifts of SSF were observed, mainly of the tritan–tetratan type. Later (after 3 months), probably as a result of activation of the compensatory correcting mechanisms of the visual system, these changes were compensated and the SSF returned to normal indices.

◆ **Firelight colour images from rod–L cone interactions**

J J McCann (McCann Imaging, 161 Claflin Street, Belmont, MA 02478, USA; e-mail: mccanns@tiac.net)

Wrangham has emphasised the role of cooking in hominid evolution. He cited evidence for the controlled use of fire as early as 1.6 million years ago. We measured the spectral exitance from flames in wood fires. It is very similar to that from a 1700 K blackbody radiator. It has nine times more relative emission than moonlight in the 600–700 nm region. Experiments have shown that complex colour images are produced by rod–L cone interactions at very low light levels, as long as there is sufficient long-wave light to excite L cones. These measurements identified the radiances for each wavelength at the transition from rod vision to cone vision. Stimuli below this cone-threshold radiance activated only rods. These techniques included dark-adaptation curves, measured action spectra, the Stiles–Crawford effect, and flicker fusion photometry. Combining complex records in 500 nm light (at 1/600th the radiance required for cone threshold)

with complex records in 656 nm light at L cone threshold generated multi-colored images. Low-light level colour and the types of illumination available 1.6 million years ago are discussed. Moonlight spectra are nearly flat from 500 to 700 nm. Using moonlight to generate multi-colour images requires more light than firelight. Firelight has a spectral emission that is optimal for seeing colour at very low-light levels from rod–L cone interactions.

COLOUR: CHROMATIC MECHANISMS

◆ About the limited additive properties of colour appearance models

M Harrar, H Brettel¶, F Viénot§ (Recherche & Développement Matériaux, Essilor International, 57 avenue de Condé, F 94106 Saint Maur des Fossés, France; also § Centre de Recherches sur la Conservation des Documents Graphiques, Muséum National d'Histoire Naturelle, CNRS, 36 rue Geoffroy St Hilaire, F 75005 Paris, France; ¶ CNRS UMR 5141, École Nationale Supérieure des Télécommunications, 46 rue Barrault, F 75013 Paris, France; e-mail: harrar@mnhn.fr)

Colour appearance models predict perceptual attribute correlates from physically measurable quantities. We used CIECAM02 to predict colour appearance changes (CAC) due to illuminant changes from a reference illuminant. We address the question whether CIECAM02 predictions of CAC for separate illuminants allow us to anticipate the CAC for the combination of illuminants. We selected illuminants with different spectral power distributions (SPDs) of about similar luminance, some of which were metameric. We selected NCS samples of known spectral reflectance. First, we predicted CAC using CIECAM02 for the separate illuminants and their averaged SPDs. We also averaged the separate illuminant predictions. Second, we conducted a psychophysics experiment with a computer simulation, asking observers to assess colour appearance by colour naming. With CIECAM02, we obtain similar hue quadrature changes from the averaged SPDs and by averaging the separate illuminant predictions (correlated coefficient: $R^2 = 0.9$) for all illuminants. In the psychophysics experiment, hue changes obtained by using the averaged SPDs and by averaging the separate illuminant responses were correlated ($R^2 = 0.73$) for metameric illuminants, but not for different illuminants ($R^2 = 0.07$). In our experiment, additive properties were found for CIECAM02 and for the visual system for metameric illuminants only.

◆ Reaction times to chromaticity, luminance contrast, size, and adaptation luminance changes

B M O'Donnell, E M Colombo (Department of Lighting, Light and Vision, Faculty of Science and Technology, National University of Tucuman, Avenida Independencia 1800, San Miguel de Tucuman 4000, Argentina; e-mail: bodonnell@herrera.unt.edu.ar)

Reaction times (RTs) in response to Gaussian coloured stimuli were measured as functions of size (0.129, 0.258, 0.22, 1.045 deg), when presented on a white background (5 and 40 cd m⁻²) with luminance contrasts around the subjective equiluminant condition up to 0.4. The chromaticity of these stimuli was varied to modulate eight vectors in colour space that included red–green and blue–yellow opponent axes. The longest RTs were obtained in response to equiluminant stimuli that isolated S-cone activity; the shortest to stimuli that modulated along the L–M opponent axis, as has been reported earlier. The difference was less than 100 ms. When the size or adaptation luminance increased, maximum RTs and the difference between opponent channels both decreased. RTs showed a tendency to a common value (350 to 400 ms) as the contrast luminance increased. RTs were highly sensitive to smallest sizes, presumably owing to inhomogeneities in retinal photoreceptors. The size of the stimulus along the blue–yellow axis was found to play the dominant role in the rapidity of the RTs, whereas adaptation luminance had a marked effect on RTs along the L–M axes. The values of RTs for the intermediate axes lie between opponent-channel values consistent with models of precortical colour processing. However, when chromatic stimuli are scaled in terms of equal multiples above the detection threshold, RT differences between opponent channels are less than 30–40 ms.

[Supported by E345/1 CIUNT PIP5013 CONICET PICT 13 15190 ANPCyT.]

◆ Global colour perceptions derived from multi-coloured texture patterns

S Sunaga, Y Yamashita, H Tanaka (Faculty of Design, Kyushu University, 4-9-1 Shiobaru, Minami-ku, Fukuoka 815-8540, Japan; e-mail: sunaga@design.kyushu-u.ac.jp)

We often call a non-uniform coloured object, which consists of many similar colours, with a single colour name. This suggests that we have an ability to perceive a single colour as the global impression of similar colours. We have examined the colour mechanism integrating the multiple colours to produce the single-colour impression. Here, the colours of the global impressions were determined by the asymmetrical colour-matching method. A multi-coloured texture pattern and a uniform field were presented on a CRT display. The texture was made by random patches having one of two colours that were different in Munsell hue though equal in Munsell value

Thursday

and Munsell chroma. The patch size ranged from 2 to 8 min of arc. Observers were requested to adjust the colour of the uniform field to match the perceived single-colour impression for the two-coloured texture. The results showed that the global impression tended to be the colour that had the same Munsell chroma as that of the dots rather than the averaged chromaticity. This suggests that the single-colour impression of a multi-coloured texture may be determined by the colour mechanism integrating the colour attributes of hue, saturation, and lightness of the elements in the texture.

[Supported in part by a Grant-in-Aid for the 21st Century COE Program 'Design of Artificial Environments on the Bases of Human Sensibility', Kyushu University, Japan.]

◆ **Optimising the strength of the watercolour effect by varying the chromatic arrangement of the inducing contours**

F Devinck, J Hardy¶, P B Delahunt¶, L Spillmann, J S Werner§ (Abteilung Allgemeine Psychologie, Justus-Liebig-Universität, Otto-Behagel-Strasse 10F, D 35394 Giessen, Germany; ¶ Posit Science, San Francisco, USA; § Department of Ophthalmology and Vision Science, University of California at Davis, 4860 Y Street, Suite 2400, Sacramento, CA 95817, USA; e-mail: Frederic.Devinck@psychol.uni-giessen.de)

The watercolour effect (WCE) is a long-range colour-assimilation effect. When a dark chromatic contour surrounds a lighter chromatic contour, the lighter colour will assimilate over the entire enclosed area. We measured the effects of chromatic modulation along the dimensions of relative hue, colorimetric purity, and cone modulation of the double contour on the strength and direction of chromatic assimilation in the WCE using the hue-cancellation method. The first experiment indicated that a stronger WCE was obtained when the inner and outer contours had chromaticities in opposite direction in colour space compared to other colour directions. In the second experiment, results showed that increasing the colorimetric purity of the outer and inner contour increases the shift in chromaticity of the WCE. However, no additional gain in effect magnitude was obtained when the colorimetric purity increased beyond a value corresponding to an equal vector length between the inner and outer contour. Finally, the results of the last experiment indicated that an (L–M)-cone-modulated WCE was perceptually stronger for eliciting the WCE than an S-cone-modulated WCE when the WCE was scaled in chromatic discriminability. Our data suggest that the WCE depends critically upon the specific spatio-chromatic arrangement in the display.

◆ **Neurophysiological evidence for categorical perception of colour**

A Clifford, A Franklin, A Holmes¶, I R L Davies (Department of Psychology, University of Surrey, Guildford GU2 5XH, UK; ¶ School of Human and Life Sciences, Whitlands College, Roehampton University, Holybourne Avenue, London SW15 4JD, UK; e-mail: a.clifford@surrey.ac.uk)

Categorical perception of colour is demonstrated by faster and more accurate discrimination of colours that cross a category boundary, compared to equivalently spaced colours from the same colour category. There is an abundance of work on colour processing and categorical perception (CP); however, the underlying mechanisms responsible for colour CP effects remain unresolved. The findings of previous behavioural studies have failed to ascertain the relative contributions of perceptual, linguistic, memorial, and decision processes. We addressed these issues by measuring event-related potentials (ERPs) to explore the time-course of within-category versus between-category colour discrimination. During a visual oddball task, ERPs were recorded for responses to frequent repetitions of a coloured stimulus (eg blue), and responses to infrequent presentations of two alternative coloured stimuli, one within-category (eg blue), and one between-category (eg green). The N2/P3a orienting complex and the N400 component were analysed to reveal the perceptual and post-perceptual processes involved during categorical responding. The investigation provides novel neurophysiological data on colour CP, and results are related to the debate about the origin and nature of colour categorisation.

◆ **Differences in sensitivity of different cone types in the parafovea measured with a Landolt C recognition task**

M V Danilova, T V Demchenko¶ (Pavlov Institute of Physiology, Russian Academy of Sciences, nab. Makarova 6, 199034 St Petersburg, Russia; ¶ State Polytechnic University, Politekhnikeskaya 29, 195251 St Petersburg, Russia; e-mail: dan@pavlov.infran.ru)

Contrast thresholds for resolving a Landolt C were measured for L-, M- and S-cones. The stimuli were presented to the left or right of fixation with their centres located 5 deg peripherally. Colours were generated with the Stockman–Sharpe 10° fundamentals. The targets were either increments or decrements from a background that had the chromaticity of equal-energy white. The observers' task was to report the orientation of the test. A series of sizes were used with the

gaps varying from 0.14 to 0.7 deg (the corresponding diameters were 0.7–3.5 deg). For all types of the stimuli, the incremental contrast thresholds were larger than the decremental ones when measured relative to the corresponding values of the background. For a given target size, M-cone thresholds were larger than the L-cone thresholds. As the size of the Landolt C increased (the gap size increased from 0.14 to 0.7), the ratio (M-threshold)/(L-threshold) on average decreased from 2.7 to 1.3, ie with increasing size of the target the difference between the L- and M-cone thresholds diminished. The rate of decrease varied among the observers. The S-cone contrast thresholds were 10 times larger than L-cone contrast thresholds.
[Supported by the Wellcome Trust 072684/Z/03/Z.]

◆ **Spatial summation for chromatic stimuli with changes in adaptation level**

T Redmond, M B Zlatkova, D F Garway-Heath[¶], A Vassilev[§], R S Anderson
(Vision Science Research Group, School of Biomedical Sciences, University of Ulster, Coleraine BT52 1SA, Northern Ireland, UK; [¶] Glaucoma Research Unit, Moorfields Eye Hospital, 162 City Road, London EC1V 2PD, UK; [§] Institute of Physiology, Bulgarian Academy of Sciences, Acad G Bonchev Street 23, BG 1113 Sofia, Bulgaria; e-mail: Redmond-T@ulster.ac.uk)

Achromatic light adaptation reduces the area of spatial summation, possibly owing to increased centre-surround antagonism in the receptive field, thus permitting higher resolution (Barlow, 1958 *Journal of Physiology* **141** 337–350; Glezer, 1965 *Vision Research* **5** 497–525). We investigated changes in spatial summation for the S-cone pathway, from dark-adapted state to saturation, guided by the fact that S-cone-mediated ganglion cells are not known to exhibit a centre-surround mechanism. S-cones were isolated with a yellow adapting field (4.5 log td) based on measured threshold-versus-intensity functions (Stiles two-colour threshold method). Spatial summation curves were determined for three blue adaptation levels (0, 1.74, and 2.04 log td), at 200 ms stimulus duration at 10° eccentricity in the temporal retina. We found that complete spatial summation (Ricco's area) does not differ notably with changes in blue background luminance, unlike changes in resolution previously found for this pathway. If Ricco's area for achromatic stimuli decreases with background luminance as a result of increased centre-surround antagonism, our results are what would be expected from changes in background luminance for a non-concentric receptive-field system.

◆ **Mechanisms of simultaneous colour contrast**

J M Bosten, J D Mollon (Department of Experimental Psychology, University of Cambridge, Downing Street, Cambridge CB2 3EB, UK; e-mail: jmb97@cam.ac.uk)

Two mechanisms for simultaneous colour contrast have traditionally been proposed. By one account, a surrounding field is thought to induce its complementary colour via lateral interactions within the visual system. By the other account, the visual system compensates for what it interprets as the illuminant. The predicted effects of these mechanisms are usually in the same direction, but it is possible to separate them by using appropriate stimuli. In all our conditions, a test patch was surrounded by elements of higher average $S/(L+M)$ value. In a 'noise' condition, these pixels were spatially arranged at random. In a second 'three-dimensional' condition, the same pixels were rearranged to give an image of objects whose chromaticity gradients implied an illuminant of lower $S/(L+M)$ than the test patch. In a third condition, the background was a uniform field with the same average luminance and chromaticity as the first two fields. If an illuminant of low $S/(L+M)$ is inferred only when chromaticity gradients adopt plausible geometrical configurations, then we should expect a difference between conditions. When the patch was embedded in uniform field, but not when it was in a three-dimensional context, observers matched it to a reference patch of lower $S/(L+M)$. The noise field gave an intermediate result. This opposes the idea that simultaneous contrast arises only from induction of the complementary hue, and suggests a second mechanism that discounts an implied illuminant.

[Supported by the Medical Research Council.]

◆ **Redundant target effect and chromatic channels of processing**

N C Ridgway[¶], A Sahraie[¶], M Milders ([[¶] Vision Research Laboratories], School of Psychology, University of Aberdeen, Aberdeen AB24 2UB, Scotland, UK; e-mail: n.ridgway@abdn.ac.uk)

Reaction times (RTs) to the onset of a single stimulus are slower than those to multiple targets. This is termed the redundant-target effect (RTE) and the reduction in RT is termed the redundancy gain (RG). RG for luminance-defined targets is often explained by a neuronal co-activation model which assumes that neuronal activation elicited by multiple targets summate to reach detection thresholds faster, resulting in faster RT. For isoluminant chromatic targets, a probability summation model appear to fit the RG data. A number of studies have indicated that activity

Thursday

in superior colliculus (SC) is responsible for neuronal co-activation, hence, signals bypassing SC should fit the probability summation model. We have applied a dynamic random luminance modulation technique (RLM) to mask out the luminance contributions of stimulus onsets. Therefore, visual targets are detected on the basis of chromatic content specified in cone excitation signals. The preliminary data indicate that RGs for chromatic stimuli at 3 times detection thresholds are similar for L and S cone signals. Luminance-defined targets equated for salience resulted in a significantly faster RT. However, the RG was similar to those of the chromatic targets. The findings are discussed in terms of probability summation and co-activation models.

- ◆ **Investigating memory colours of natural objects: A new method of chromatic adjustment**
M Olkkonen, T Hansen, K R Gegenfurtner (Department of Psychology, University of Giessen, Otto-Behaghel-Strasse 10F, D 35394 Giessen, Germany;
e-mail: maria.olkkonen@psychol.uni-giessen.de)

We recently found that observers perceive natural objects slightly tinted towards their memory colour even when their mean chromaticity is grey. In the previous experiment, chromaticity was adjusted by a shift of the chromatic distribution in colour space, causing residual chromaticity in the stimulus even when the mean value was grey. Here we use a new adjustment method that results in a pure luminance variation at the white point. We presented subjects with photographs of natural fruit and vegetable objects on a grey background embedded in a large neutral surround. Subjects made two adjustments: a setting to the typical fruit colour, and an achromatic setting. The achromatic settings were also made with uniformly coloured discs and pink noise patterns. During adjustments, the chromatic distribution was rotated and scaled relative to the white point in the isoluminant plane of the DKL colour space. Physically achromatic objects were consistently perceived tinted towards their typical colour. For an object to appear achromatic, subjects adjusted the colour by 10%–20% in the direction opposite to the typical setting. No bias was found for the synthetic stimuli. Such a clear memory colour effect might play a significant role in colour constancy for natural objects.

[Supported by the DFG grant Ge 879/5.]

- ◆ **Colour category effects on a target detection task in three age groups: A cross linguistic comparison**

O A Wright, A Franklin, I R L Davies (Department of Psychology, University of Surrey, Guildford, Surrey, GU2 7HX, UK; e-mail: o.wright@surrey.ac.uk)

Universalist accounts (eg Bornstein, 1976 *Journal of Experimental Psychology: Human Perception and Performance* **1** 115–129) of colour perception suggest that categorical colour perception (CP) is innately constrained. Relativists (eg Roberson et al, 2005 *Cognitive Psychology* **50** 378–411) suggest that colour language shapes colour perception. However, much of the evidence for colour CP comes from X–AB and same–different tasks which typically involve a delay between test and target phases. This may implicate memory and/or language rather than perceptual processes. The experiment reported here used a target detection task to provide direct evidence of colour CP. In some trials, target and background came from different colour categories, in others from the same category. Participants from two age and two language groups (English and Himba) with different colour category structures were tested. Results showed categorical patterns of response in all groups at linguistic category boundary regions, regardless of whether the boundary was marked in the participant's language. Himba speakers showed categorical patterns of responding across a boundary not marked in their language, whilst English speakers showed a similar effect across a Himba boundary. These findings provide evidence that CP really is a perceptual phenomenon. They also suggest linguistic colour categories have little effect on performance and that the origin of colour categories is 'hardwired'.

[Supported by ESRC award—PTA-030-2004-0057.]

- ◆ **Grating speed perception can be biased when associated with chromatic modifiers separated in time or space**

M Burton, D McKeefry (Department of Optometry, University of Bradford, Bradford BD7 1DP, UK; e-mail: m.p.burton1@bradford.ac.uk)

Moving luminance 'modifier' grating stimuli presented in close proximity to a test stimulus, can bias its perceived speed (Smith and Derrington, 1996 *Vision Research* **36** 3759–3766). We wished to examine the influence of modifier chromaticity on this effect, and measured the perceived speed of a test grating in the presence of chromatic and luminance modifier stimuli which moved at different speeds. In initial experiments, the modifier stimuli were temporally coincident with and directly abutted the test stimulus. Under these conditions the modifiers could bias perceived speed regardless of whether they were defined by colour or luminance. In subsequent experiments

we examined the effects of increasing the spatial and temporal separation between the modifiers and the test stimuli. Modifiers were able to influence the perceived speed of the test across separations of up to 3 s. There was a linear decrease in the magnitude of the speed bias with increasing spatial separation which fell to zero for separations above 12 deg. These results indicate that speed perception appears to be based upon a mechanism which pools motion energy over a relatively wide spatiotemporal window and is insensitive to the chromatic or luminance composition of the input signals.

◆ **Cortical areas implicated in transparency perception**

R Bouet, M Dojat¶, L Lamalle§, C Segebarth¶, K Knoblauch (Inserm, U371, Cerveau et Vision, 18 avenue du Doyen Lépine, F 69500 Bron, France; ¶ UMR Inserm/UJF, U438 RMN Bioclinique, LRC CEA, Centre Hospitalier Universitaire, Pavillon B, BP 217, F 38043 Grenoble Cedex 9, France; § IFR1, Unité IRM 3T, Centre Hospitalier Universitaire, F 38043 Grenoble Cedex 9, France; e-mail: bouet@lyon.inserm.fr)

Surface colour perception requires global integration of local tristimulus contrasts to differentiate illuminant and transparent effects from intrinsic, surface spectral characteristics. We exploited the phenomenon of transparency perception to identify cortical areas involved in such processes. In an fMRI study (3 T), fourteen observers were tested. The stimulus was a 10.3 deg field of random coloured disks (0.6 deg). Within an annular test region, 1 (inner) and 7 (outer) deg diameters, the disks were modulated (0.67 Hz) either coherently (CM) (appearing as a homogeneous transparency) or non-coherently (NCM) (appearing as flickering individual fields), along either the LM or S axis, at three modulation depths. Local modulations were identical across conditions. Saliency was controlled by outlining the border of the test field with a thin, black contour on half of the presentations. CM generated significant activity in the parahippocampus and in at least two extrastriate areas; NCM generated activity in more lateral, occipital regions. No differential effect of the saliency-inducing contour was observed. An ROI analysis of the PPA indicated partial overlap of activity with this region. The distribution of activity observed implicates a ventro-occipital network in transparency perception and suggests separate pathways for processing illuminant and material properties.

◆ **Motion-based colour integration in ambiguous motion**

J Watanabe, S Nishida¶ (PRESTO Japan Science & Technology Agency [also ¶ NTT Communication Science Laboratories], NTT Corporation, 3-1 Morinosato Wakamiya, Atsugi-shi, Kanawaga 243-0198, Japan; e-mail: watanabe@avg.brl.ntt.co.jp)

Our previous studies (Watanabe et al, 2004 *Perception* 33 Supplement, 163–164) suggested that the visual system integrates colour signals along perceived motion trajectory. We examined this hypothesis using a multi-path motion display. Colour bars [bar width (BW) = 9 min of arc] were horizontally arranged with a constant dark bar interval (BI), with their colours spatially alternated between red and green. They were horizontally shifted with a displacement of BW in a direction (say, rightward) every 100 ms, while changing their colours in red and green at every shift. When BI was large, the observers tended to see the bars moving along the rightward path (jump size = BW) with the colours alternated, which were expected to be in the mixed colour. When BI was small, the observers tended to see the bars moving along the leftward path (jump size = BI – BW) in which each bar kept its colour. We asked the observers to rate the perceived motion direction and colour mixture, while we manipulated BI. In accordance with the change of the perceived motion direction from colour-retaining path to colour-alternating path, the colour mixture rating gradually increased. This co-variation of the motion and colour ratings is predicted by our hypothesis of colour integration along perceived motion path.

[Supported by PRESTO Japan Science & Technology Agency]

◆ **A role for the blue pathway in the development of red – green opponency**

P V Maximov, D S Lebedev, D W Marshak¶ (Institute for Information Transmission Problems, Bolshoi Karetnyi, 127994 Moscow, Russia; ¶ Department of Neurobiology and Anatomy, University of Texas Medical School, 6431 Fannin Street, Houston, TX 77030, USA; e-mail: pmaximov@iitp.ru)

Cone-specific responses are generated by midget ganglion cells in primates, despite the electrical coupling of L and M cones and the unselective connections of inhibitory neurons. Lebedev and Marshak recently proposed a model of the central macaque retina that reconciled these findings. OFF amacrine cells (ACs) receiving synapses from all bipolar cells (BPs) but with a bias toward those receiving input from M cones were a key feature of that model. Here we demonstrate how this bias might develop due to activity-dependent synaptic plasticity. Our model consists of (i) array of cones, (ii) array of OFF BPs that each receive input from one cone, and (iii) OFF ACs

Thursday

that receive input from all BPs within their dendritic fields. A series of random, coloured stimuli were presented (stimulation of M and S cones being slightly correlated), and the weights of synapses from BPs to ACs were modified by using a physiologically plausible, Hebbian-like learning rule depending on the membrane potentials of the presynaptic and postsynaptic neurons. As a result, excitatory synapses from BPs with input from M cones were strengthened, and the magnitude of the effect depended on the local S cone density. These interactions would occur only in the OFF pathway.

[Supported by the program of the Russian Academy of Sciences Branch of Biological Sciences 'Physiological mechanisms for regulation of internal environment and control of behavior in living systems']

◆ **The influence of size and adaptation luminance on colour contrast threshold**

B M O'Donnell, E M Colombo (Department of Lighting, Light and Vision, Faculty of Science and Technology, National University of Tucumán, Avenida Independencia 1800, San Miguel de Tucumán, CP 4000 Tucumán, Argentina; e-mail: bodonell@herrera.unt.edu.ar)

Detection contrast thresholds of chromatic signals were measured by an adaptive psychometric procedure—QUEST—with three observers. Stimuli of different sizes—0.129, 0.258, 0.522 deg, and 1.045 deg—were presented with a Gaussian spatial and temporal cosinusoidal profiles on two equiluminant 'white' backgrounds, 5 cd m⁻² and 40 cd m⁻². Eight colour axes were investigated, four of which correspond to L–M cones and S-cones. Data plotted on the CIE 1931 chromaticity diagram show that the largest distances from 'white' correspond to the smallest stimulus sizes, while the distances are not significant for the largest sizes. RMS contrast thresholds are larger for 410 nm 'blue' and 570 nm 'yellow' wavelengths than for the 550 nm 'green' wavelength and a stimulus with a complementary wavelength of 550 nm. For the intermediate axes, RMS contrasts lie between the values corresponding to cardinal axes. The influence of adaptation luminance depends on colour; larger differences were found for blue and yellow colours than for green and red cases. The influence of adaptation luminance is higher for the smallest sizes and size is more important for 5 cd m⁻² than for 40 cd m⁻². The results are consistent with the presence of chromatic detection mechanisms responding to the tested colours and agree with previous studies. [Supported by E 345/1 CIUNT PIP 5013 CONICET PICT 13 15190 ANCPyT.]

◆ **Is there a representational momentum for colour?**

T Shahsavarzadeh, M Sanayei¶, A Najafian (Neuroscience Research Group, Isfahan University of Medical Science, Isfahan, Iran [¶] also School of Cognitive Sciences, Institute for Studies in Theoretical Physics and Mathematics (IPM), Tehran, Iran); e-mail: tshahsavarzadeh@yahoo.com)

Distortion of memory of the final location of an object or event shifted beyond its actual position has been referred to as representational momentum (RM). A series of experiments showed that RM can be seen for position and luminance. We have tried to investigate whether there is a RM for colour. Some experiences showed that there is colour flash-lag effect. Some similarities between flash-lag effect and RM caused us to look for RM for colour, directly. We showed a coloured disk to six observers; its colour changed from red to green or vice versa, and its colour changed through yellow. When the disk disappeared, we showed another disk whose colour was in the direction of the final colour or opposite to it. Observers compared the colour of this disk with the colour of the disappearing one. Their perception of the colour of the disk showed that there is an anti-RM. Subjects had points of subjective equality at 3.95 frames, which is about 246 ms and is significantly different from zero (*t*-test, *p* < 0.0005, frame duration = 62.5 ms). It seems that colour involves a different mechanism for RM; and may be the underlying basis for representation of colour is different from other object dimensions.

[Supported by Talented Office, Medical Education Development Center, Isfahan University of Medical Science, Isfahan, Iran.]

COLOUR: CLINICAL

◆ **Colour-vision tests for monitoring of visual functions in persons with multiple sclerosis**

R Lukauskienė, V Viliunas¶ (Department of Neurosurgery, Kaunas University of Medicine, Eiveniu 2, LT 50009 Kaunas, Lithuania; ¶ Institute of Materials Science and Applied Research, Vilnius University, Sauletekio 9-III, LT 10222 Vilnius, Lithuania; e-mail: lukarita@yahoo.com)

Monitoring of colour vision in patients with optic nerve atrophy is a sensitive method for the evaluation of visual function dynamics, even if visual acuity or visual fields remain intact. The computerised Farnsworth–Munsell (F–M) 100-hue test and the colour threshold test were used. Hue discrimination and colour-determination thresholds were measured in forty-five patients with optic nerve atrophy caused by multiple sclerosis and fifty age-matched healthy persons.

The visual acuity of patients varied from 20/25 to 20/200 on the Snellen chart. The results were analysed according to: (i) the mean of F–M 100-hue test error scores; (ii) the mean of colour-determination thresholds; (iii) colour deficiency type as revealed by the F–M 100-hue test; (iv) colour deficiency as revealed by the colour thresholds test. The changes of the red–green selective scores in persons with optic nerve atrophy were almost identical to the changes of the blue–yellow selective error scores. There was no strong correlation between the total error scores of the F–M 100-hue test and the vision acuity scores (correlation coefficient 0.42). The strong correlation between the mean error score of the F–M 100-hue test and the mean of colour threshold (correlation coefficient 0.86) was estimated.

◆ **Colour-perception changes in persons with epilepsy**

B Budiene, R Lukauskienė*, V Viliunas§ (Eye Clinic [*Neurosurgical Clinic], Kaunas University of Medicine, Eiveniu 2, LT 50009 Kaunas, Lithuania; §Institute of Materials Science and Applied Research, Vilnius University, Sauletekio al.9-III, LT 10222 Vilnius, Lithuania; e-mail: luka.rita@yahoo.com)

We sought to characterise the dyschromatopsia in seventy-five persons with focal epilepsy and eighty normal controls. The age of persons ranged between 16–50 years. Visual acuity of patients was normal. None of the studied patients complained of colour-vision disturbances. All persons with epilepsy were taking AEDs. Computerised Farnsworth–Munsell 100-hue test was used for testing of patients. All of the statistics were calculated from the square root of the total and selective error scores. We used quantitative analysis of F–M 100-hue test error scores to determine the severity, the selectivity, and the type of dyschromatopsia. Colour perception was impaired in 87% of the study group with epilepsy. The changes of the red–green selective scores in observers with epilepsy were almost identical to the changes of the blue–yellow selective error. It can be stated that AEDs can show some negative effect upon colour discrimination, and colour discrimination tests can be a sensitive method to estimate the colour-perception deficiency.

◆ **A computerised test for identification of colour thresholds in prosopagnosia**

D Stanislovaitienė, R Lukauskienė, V Viliunas* (Neurosurgical Department, Kaunas University of Medicine, Eiveniu 2, LT 50009 Kaunas, Lithuania; *Materials and Applied Science Institute, Vilnius University, Sauletekio 9-III, LT 2052 Vilnius, Lithuania; e-mail: luka.rita@yahoo.com)

Two prosopagnostic patients with damage of both temporal lobes and fifty age-matched healthy persons were tested. During the test, the observers were shown a computer-generated stimulus. The stimulus consisted of a line surrounded by a grey background 2 deg in diameter. The colour saturation of the line varied by increasing or decreasing its red, green, or blue phosphor luminance, starting from the initial grey of the background. The brightness of the grey background was increased or decreased from its initial brightness towards the brightness of the line. Simultaneously, the orientation of the line was randomly varied between horizontal and vertical. The observers were asked to judge the orientation of the line. The saturation threshold was established when the observer was not able to accurately detect the orientation. The mean of colour threshold test was 2.6 times worse in persons with prosopagnosia than in healthy persons. It was 3.1 times worse for red colour, 2.1 times worse for green, and 2.6 times worse for blue colour. The test for identification of colour thresholds is preferable to the Farnsworth–Munsell 100 hue test, as it allows estimation of all deficiency types separately and dynamic monitoring of colour perception.

◆ **Functional spectral filter optically simulating colour discrimination property of dichromats**

K Miyazawa, T Onouchi*, H Oda, K Shinomori§, S Nakauchi* (Itoh Optical Industrial Co. Ltd, 3–19 Miyanari-cho, Gamagori 443-0041, Japan; *Department of Information and Computer Sciences, Toyohashi University of Technology, 1-1 Hibarigaoka Tempaku, Toyohashi 441-8580, Japan; §Department of Information Systems Engineering, Kochi University of Technology, 185 Miyakokuchi, Tosayamada-town, Kami-city, Kochi 782-8502, Japan; e-mail: k-miyazawa@itohopt.co.jp)

We are gradually recognising the importance of colour universal design in which designers should avoid confusing colour combinations in documents for colour defectives as well as for people with normal colour vision. However, it is not always easy to avoid those confusing colours because it is difficult to describe them only by words in a manual and a special kind of software or a chart with hundreds of colour combinations are needed. Here, we propose the functional spectral filter with which users with normal colour vision can easily find the confusing colour combinations for dichromats. Spectral transmittance of the filter was designed so that the amount of colour differences for a normal observer with the filter would be close to that for colour dichromats. The designing process of the filter was formulated as an optimisation problem

Thursday

of minimising the discrepancy in colour differences between people with normal vision provided with the filter and dichromats. Evaluation results with a real filter produced by vacuum deposition technology for Ishihara plates, Panel D-15 test and colour discrimination ellipse (Cambridge Colour Test) indicated that observers with normal colour vision with the filter are similar to dichromats in their colour discrimination.

[Supported by the Regional New Consortium Projects from the Ministry of Economy, Trade and Industry of Japan.]

FINE EYES AND ARTS

- ◆ **Composition rules for photography based on physiology and psychology of human vision**
D V Korablev (St Petersburg State University of Cinema and Television, Pravyd 13,
St Petersburg 191002, Russia; shipov_d@rambler.ru)

Traditional composition laws in photography are supported but their number is reduced. The proposed rules are based on visual perception algorithms. The basic composition rules are: invariant perception of images, priority of different image parts depending on their perceptual importance (focuses of attention, meaningful centres), specific perception of groups and textures, the effect of contour extension, perception of lines and contours, high-frequency and low-frequency filtration, rhythm, peculiarities of perception of movement, of glance, of action, Golden section, tunneling effect. Composition laws lead to lively photographs—appreciated by the observer. If we break them, we obtain photographs full of negative emotions. Many canons of classical photography have been revised. For example, generally accepted six types of illumination have been replaced by two types which are based on our perception. This makes the work of a photographer easier. Recently, many changes have been made in portrait shooting. Knowledge of compositions rules allows the photographer to determine almost immediately how photogenic the face and the figure of a model are. Giving priority to meaningful centres helps to create a good portrait.

- ◆ **Effects of photographic techniques and affective responses on preference and aesthetic appreciation of photography**
W H Jung, J Han¶, S Shin, S Park§ (Center for Cognitive Science, Yonsei University,
Sinchon-dong, Seodaemooon-gu, Seoul 120-749, Korea; ¶ Behavioral Science Research
Center, Korea University, Anam-dong, Seongbuk-Gu, Seoul 136-701, Korea; § College
of Social Science, Chungbuk National University, Gaesin-dong, Heungduk-gu, Cheongju,
Chungbuk 361-763, Korea; e-mail: com4man@gmail.com)

The effects of photographic techniques and affective impressions on preference and aesthetic appreciation of a photograph were investigated. In the first study, we examined the relationships between three dimensions of impressions (positive–negative, static–dynamic, light–heavy), and between three dimensions of affections and aesthetic appreciation. The results showed that the positive–negative affective impression was the principal dimension in preference and aesthetic appreciation. In the second study, we investigated the effects of photographic techniques and visual properties on preference and aesthetic appreciation. The results demonstrated that preference was affected by colour tone of the photo-image, especially blue tone. The aesthetic appreciation was influenced by the location of main subjects and the position of the camera: the aesthetic appreciation of photographic images was raised if the locations of main subjects were not centred, the position of the camera was low, and the forms of main subjects were exaggerated.

[Supported by Korea Research Foundation Grant funded by Korea Government (MOEHRD, Basic Research Promotion Fund) KRF-2005-079-GS0008.]

- ◆ **Judgments of paintings**
S Marković, A Radonjić¶ (Laboratory of Experimental Psychology, University of Belgrade,
Čika Ljubina 18–20, 11000 Belgrade, Serbia; ¶ Department of Psychology, Rutgers University,
101 Warren Street, Newark, NJ 07102, USA; e-mail: smarkovi@f.bg.ac.yu)

We investigated the structure of the judgments of paintings. In the preliminary study, ninety-three subjects were asked to describe their subjective experience of paintings, producing a list of attributes. The set of 43 most frequent attributes was selected and transformed into a bipolar 7-step scale. The stimulus set was made up so that the 24 representative paintings were taken from the previous study of similarity judgments of paintings and their distribution in multi-dimensional scaling space (Radonjić et al, 2004 *Perception* 33 Supplement, 88). These 24 paintings were grouped into four categories: (i) primitive art, (ii) figural realism, (iii) stylised realism, and (iv) abstract paintings. In this study, twenty-one subjects judged paintings on 43 scales. A complex matrix was generated: matrices for all 24 individual paintings were set one under the other. In the factor analysis, the following five factors were extracted: regularity (scales: precise, clear, regular, etc), arousal (unusual, imaginative, impressing, etc), attraction (beautiful, pleasant, healthy,

etc), evaluation (clever, balanced, interesting, etc), and serenity (unimposing, tender, serene, etc). The results suggest that the obtained factors can be taken as a basis for a quantitative definition of the subjective experience of paintings.

◆ **A visual anisotropy on aesthetic preference**

K Mitsui, K Shiina (Graduate School of Library, Information, and Media Studies, University of Tsukuba, 1-2 Kasuga, Tsukuba-city, Ibaraki 305-8550, Japan; e-mail: mitsui@slis.tsukuba.ac.jp)

When a pair of disks equal in size was presented at different orientations in a rectangular framework, aesthetic preference value was highest at the vertical as well as at the horizontal orientations (Mitsui and Noguchi, 2003, Annual Meeting of the 6th Asian Design Conference, Tsukuba, Ibaraki, Japan). On the other hand, when a pair of disks different in size was presented at different orientations in the same framework, aesthetic preference value was highest at the vertical orientation (Mitsui et al, 2005 *Perception* 34 Supplement, 87). The present study replicated similar tasks but with a circular framework under three kinds of instructions: (i) asking his/her aesthetic judgment and preference of arrangement, (ii) asking his/her aesthetic judgment, and (iii) asking his/her preference, independently. The results showed that a visual anisotropy was found in almost the same pattern in the circular framework as in the rectangular framework, and almost the same appearance of the anisotropy was found under the three kinds of instructions.

◆ **Setting the trend: When attractiveness is a matter of adaptation**

C-C Carbon, T Ditye, H Leder (Department of Psychological Basic Research, Faculty of Psychology, University of Vienna, Liebiggasse 5, A 1010 Vienna, Austria; e-mail: ccc@experimental-psychology.com)

What do we like and, most interestingly: what will we like in the future? In recent years, research on figural aftereffects has shown that the inspection of distorted objects biases the perception in a subsequent test phase towards the shape of the inspected stimuli. Here we show that it is not only perception but also preferences that can be biased in the way just described. In a series of experiments we tested the hypothesis that aftereffects related to preferences do not only hold for specific attributes of single stimuli but also for more abstract stylistic information relevant for a whole class of stimuli. We employed an adaptation paradigm: participants had to inspect exemplars of highly distinctive fashion styles, and before and after this inspection phase they were to evaluate the preferences for other exemplars. A comparison of the data from both measuring points revealed that participants who initially preferred familiar exemplars shifted their preferences towards the more extreme styles. In sum, this indicates that even fashion trends can be explained on the basis of adaptation effects.

◆ **Lighting effects on affective impressions of photographs**

S Park, S Shin ¶, J Han§, W H Jung ¶ (College of Social Science, Chungbuk National University, Gaesin-dong, Heungduk-gu, Cheongju, Chungbuk 361-763, Korea; ¶ Center for Cognitive Science, Yonsei University, Sinchon-dong, Seodaemoon-gu, Seoul 120-749, Korea; § Behavioral Science Research Center, Korea University, Anam-dong, Seongbuk-Gu, Seoul 136-701, Korea; e-mail: happyalo@gmail.com)

We performed this study to confirm that lighting effects can change affective impressions of photographs. The stimuli were images of living things, a natural scene, and architectures. The affective impressions were evaluated on a 7-point scale based on three affective dimensions (Park et al, 2004 *Korean Journal of the Science of Emotion & Sensibility* 7 41–49). In experiment 1, the original images and images with four kinds of light effects were compared—lighting from: top left, top right, bottom left, and bottom right. On the positive–negative impression, lighting effects from top left and bottom left were more negative than the original. On the static–dynamic impression, the images with lighting effects of all directions made the original change to a more dynamic impression. There was no difference of affective impressions between the original image and the lighting effect of any direction on the light–heavy impression. In experiment 2, original images, the images of highlighting centre (HC), and the images of blurred background (BB) were compared. BBs were more negative, more dynamic, and heavier than the original, but there was no difference of impressions between HC and the original. These results imply that change of lighting position can affect perceived position of emphasised area of images and it affects overall cognitive process and affective impressions.

[Supported by Korea Research Foundation Grant funded by Korea Government (MOEHRD, Basic Research Promotion Fund) (KRF-2005-079-GS0008).]

Thursday

◆ **How does knowledge in art influence perception of space and motion evoked by paintings of Francis Bacon**

Z Kapoula, L J Lestocart¶ (Iris Group, CNRS, Collège de France, 11 place Marcellin Berthelot, F 75005 Paris, France; ¶ Critique d'Art, ArtPress, 8 rue François Villon, F 75015 Paris, France; e-mail: zoi.kapoula@college-de-france.fr)

The study was conducted at the Maillol museum during the exhibition "Le sacré et le profane" (Paris, 2004). Twenty-nine observers (nineteen artists or working in the art domain, ten scientists) participated. Their eye movements were recorded with a video system (Chronos). Questions on their perception were asked afterwards. Results are presented for the painting "Study of a dog" (1952). This painting depicts a plane in depth with a dog in a circle, cars, trees, and a horizon line; another horizontal line induces a vertical perpendicular plane. Only half of the subjects (of either group) perceived two planes. Yet, eye movements showed that most of the subjects in the art group explored a large surface of the painting including the vertical plane and other spatially important points. In contrast, many of the scientists explored almost exclusively the narrative points (dog and cars). Such differences (narrative vs spatial eye scanning) appeared from the first 3 s. Moreover, the art group reported vivid perception of circular motion of the dog – circle, whereas scientists were almost blind to such motion. Thus, prior knowledge influences even pictorial motion perception.

◆ **From the square to Malevich's square: How the brain creates meanings**

B Pinna (Dipartimento di Scienze dei Linguaggi, Università di Sassari, via Roma 151, I 07100 Sassari, Italy; e-mail: baingio@uniss.it)

In visual perception, the square is an emergent form, ie a perceptual 'meaning' defining its components (sides and angles) and being defined by them. The emergence of the square depends on how elements in the visual field 'go together' to form a holistic percept. The perceptual meaning of both the whole form (the square) and the individual components (sides and angles) is emergent and reciprocally determined. In visual arts (Suprematism) 'Malevich's square' is the extreme reduction of art: the supremacy of pure feeling. Art is reduced to nothing more than a black square on a white background. Art is created as an emergent meaning by a non-objective representation. Main questions of this work are: What is a perceptual emergent meaning going from the square to art? What are the visual-organisation principles underlying the formation of meanings? How does the brain create meanings? To answer these questions: new phenomena, called 'illusions of meanings', are reported; (i) they phenomenally show different degrees of perceptual abstraction, and (ii) allow to extract the 'laws of perceptual meanings' that reduce the question of what is a meaning to the problem of visual organisation and suggest a possible neural scenario.

[Supported by Fondazione Banco di Sardegna, Alexander von Humboldt Foundation, PRIN ex 40% Cofin. es. 2005 (prot. 2005112805_002) and Fondo d'Ateneo (ex 60%).]

◆ **Making good hidden figures**

K Mogi, Y Tamori¶ (Sony Computer Science Laboratories, Takanawa Muse Building, 3-14-13 Higashi-Gotanda, Shinagawa-ku, Tokyo 141-0022, Japan; ¶ Human Information System Laboratories, Kanazawa Institute of Technology, Ishikawa 921-8501, Japan; e-mail: kenmogi@qualia-manifesto.com)

Hidden figures are interesting perceptual phenomena where it takes some time to perceive what is hidden in a seemingly ambiguous bi-level quantised image. Famous examples such as 'the Dalmatian' [Gregory 1970 *The Intelligent Eye* (London: Weidenfeld & Nicolson)] and 'Dallenbach's cow' are good stimuli to be used in experiments on visual one-shot learning (Mogi et al, 2005 *Perception* 34 Supplement, 15–16). Obtaining many good examples of hidden figures can facilitate the research into visual one-shot learning, where a stimulus can be presented to a subject only once. However, 'good' hidden figures, in which the initial ambiguity turns into a final definite perception of the hidden object, are difficult to make. Preliminary investigations have shown that a simple quantisation of images almost always results in an obvious and immediate perception of the object. Band filtering based on Fourier transform generally leads to a malevolent disruption, making it difficult and unconvincing to perceive the object. Here we report an attempt to produce good hidden figures in a systematic way. We describe several algorithms combining mathematical modeling and 'heuristics by hand', in cooperation with Japanese cartoonists. On the basis of the result, we discuss the conditions for good hidden figures, and the implications for the neural mechanisms involved.

◆ **The repeated evaluation technique or 'how can we measure attractiveness in a valid way'?**

C-C Carbon (Faculty of Psychology, Department of Psychological Basic Research, University of Vienna, Liebiggasse 5, A 1010 Vienna, Austria; e-mail: ccc@experimental-psychology.com)

So far, attractiveness has mostly been measured only once, in single-shot studies. Yet, in reality it seems to be a very dynamic variable: specific preferences for faces, objects, or consumer

products develop over time. This makes it necessary to measure attractiveness in more complex settings during which participants are familiarised with the objects of interest. In a series of studies an attempt was made to achieve this aim by employing the so-called repeated evaluation technique (RET) (Carbon and Leder, 2005 *Applied Cognitive Psychology* **19** 587–601). RET simulates everyday experiences by not only exposing participants massively to the stimuli but also having them evaluate the stimuli in many different aspects. The idea of this procedure is to deepen participants' understanding of the material. Experiments with RET have shown that, for instance, highly innovative products benefit from elaboration and familiarisation, whereas preferences for more conservative, less innovative products drop over time. Therefore, RET seems to be an appropriate technique to be used in applied studies concerned with preferences, attractiveness, and concepts of innovativeness.

AUDIOVISUAL INTERACTION

◆ **Influence of visual load on 'automatic' detection of auditory change**

K Haroush, L Y Deouell¶, S Hochstein§ (Institute of Life Sciences [¶ Psychology Department; § Life Sciences Institute and Interdisciplinary Center for Neural Computation], Hebrew University, IL 91904 Jerusalem, Israel; e-mail: kharoush@gmail.com)

When attention is focused on a central task, background processes monitor the environment, detecting potentially important changes, and allowing reallocation of attention. The auditory mismatch negativity (MMN) event-related potential reflects such an automatic process. We tested whether auditory and visual processing share attentional resources, and asked if attention manipulation is related to frontal, rather than temporal MMN components. We used the attentional-blink paradigm with variable load. Participants reported identities and order of two digit targets (T_1 , T_2) embedded in a rapid letter stream. We found a significant load effect on T_1 and T_2 performance, on the length and depth of the attentional blink, and on the degree of $T_1 \leftrightarrow T_2$ order switching. We introduced background standard sounds with infrequent pitch deviants, which subjects ignored. The MMN is the difference between the average standard and average deviant EP response. Current source density distributions were used to index frontal and temporal MMN components. MMN amplitude decreased and its latency increased significantly as visual load increased. These attentional load effects were not differential for frontal and temporal MMN generators, and the right frontal area was immune to load. These results question the current neuronal network model of auditory change detection.

[Supported by Israel Science Foundation 'Center of Excellence' and US–Israel Binational Science Foundation.]

◆ **Integration of visual and auditory motion signals in the human brain: an MEG study**

J E Aspell, T Tanskanen¶, A C Hurlbert§ (Department of Experimental Psychology, University of Oxford, South Parks Road, Oxford OX1 3UD, UK; ¶ Brain Research Unit, Low Temperature Laboratory, Helsinki University of Technology, Espoo, Finland; § Department of Psychology, Institute of Neuroscience, University of Newcastle upon Tyne, Framlington Place, Newcastle upon Tyne NE2 4HH, UK; jane.aspell@gmail.com)

To investigate the neural basis of cross-modal interactions, we measured transient responses to combined and separate visual and auditory motion stimuli using magnetoencephalography (MEG). Six participants viewed random-dot kinematograms while listening to sound movement simulated by interaural amplitude modulation of a pure tone. Each 'AV' trial began with a 'noise' phase, during which the dots moved at random while the sound remained stationary, followed by a 'coherent' phase, during which the dots moved together leftwards or rightwards, while the sound moved in the same or opposite direction. In 'A' trials the dots remained stationary throughout, and in 'V' trials the sound remained stationary throughout, but otherwise the trials were identical to 'AV' trials. We compared the grand average response waveforms for the sum of the unimodal conditions ($A + V$) with the bimodal conditions (AV), for the three time periods corresponding to maximal waveform peaks (stimulus onset and motion transition). In each period, the grand average of ($A + V$) responses was greater than the grand average for AV. Source modeling revealed an interaction source, active in 'AV' but not 'A+V', which was localised to the superior temporal sulcus for four participants, and to the human MT complex for two participants. [Supported by the Wellcome Trust, EU Neuro-Birch III, and a MRC studentship.]

◆ **Motion-specific auditory – visual integration measured by event-related potentials**

N R Harrison, G F Meyer, S M Wuerger (School of Psychology, University of Liverpool, Eleanor Rathbone Building, Bedford Street South, Liverpool L69 7ZA, UK; e-mail: neilrh@liv.ac.uk)

The rapid integration of signals across modalities is essential for an accurate representation of the environment. Here, we tested whether there exist motion-specific auditory–visual neural

Thursday

integration mechanisms by comparing auditory–visual interactions obtained for moving and for stationary stimuli. We collected event-related potentials (ERPs) from one group of participants who performed a reaction-time task where participants had to respond to the direction of a moving stimulus. A separate group of participants performed a reaction-time task where they responded to a stationary target stimulus. The modality of the target stimulus was either unimodal (visual or auditory), or bimodal (visual and auditory). An ‘additive’ model was used to assess ERP crossmodal effects by calculating $AV - (A + V)$ residuals (Besle et al, 2004 *Cognitive Processing* **5** 189–192). We found significant reaction-time facilitation for the bimodal condition in both groups, which could not be explained by an independent processing (‘race’) model. Significant differences between the moving and stationary $AV - (A + V)$ residuals were observed at 140–170 ms and 240–260 ms post-stimulus. Both behavioural and ERP results therefore suggest that there exist motion-specific early sensory interactions between auditory and visual signals.

◆ **Auditory-induced bounce perception when visual trajectories are inconsistent with motion reversal**

K Sakurai, P M Grove¶ (Department of Psychology [¶ Graduate School of Human Informatics], Tohoku Gakuin University, 2-1-1 Tenjinzawa, Izumi-ku, Sendai 981-3193, Japan; e-mail: sakurai@mind.tohoku-gakuin.ac.jp)

An auditory click at the point of coincidence in stream/bounce displays produces a robust bias toward bounce perception. We investigated whether this bias would be observed when the objects’ trajectories have a spatial offset. In experiment 1, the targets (subtending 51.2 min of arc), presented on a 2-D display, were vertically offset from one another from 0 to 25.6 min of arc. In experiment 2, stereoscopically presented targets were displaced in depth relative to each other (disparity ranged from 0 to 25.6 min of arc). In both experiments, offset conditions were combined with two auditory conditions: sound at coincidence, no sound at coincidence. Observers indicated whether the targets appeared to stream past or bounce off of one another (reverse their direction of motion). When no sound was presented, streaming was seen in nearly 100% of the trials, regardless of spatial offset. When a sound was presented at the point of coincidence, bouncing was dominant and persisted with increasing 2-D and 3-D trajectory offsets. An auditory click modified the trajectory of the targets such that they appeared to make a ‘U-turn’ at the point of coincidence. Our results extend previous reports, showing that unambiguous visual displays can be perceptually modified by auditory stimulation.

◆ **Other’s gaze direction affects sound localisation**

H Sukemiya, K Miura, Y Yamada¶, T Kawabe§ (Faculty of Human–Environment Studies [¶ Department of Behavioral and Health Sciences, Graduate School of Human–Environment Studies; § User Science Institute], Kyushu University, 6-19-1, Hakozaki, Higashi ward, Fukuoka 8128581, Japan; e-mail: sukemiya@psycho.hes.kyushu-u.ac.jp)

We investigated the effect of other’s gaze as attentional cue on sound localisation. In experiment 1, by using manual pointing task to a sound source, we examined the accuracy of sound localisation when target sound and gaze cue were presented simultaneously. Results showed that perceived location of target sound was displaced in the gaze direction, when target sound was presented in the spatial field of the gaze, although this effect disappeared when it was presented in the opposite one. In experiment 2, we manipulated stimulus onset asynchrony (SOA) between onsets of target sound and gaze cue. Results showed that perceived location of target sound was biased toward gaze direction as in experiment 1, at short SOAs of less than 300 ms, regardless of whether or not the gaze cue appeared temporally ahead of sound. In contrast, this facilitatory effect disappeared at long SOAs of 700 ms. Overall, the results indicate that the visual attentional cue of other’s gaze causes an attention shift in auditory as well as visual spaces, and that it can effectively work within a short temporal separation (ie within 300 ms) between visual and auditory events.

◆ **Perceptual shifts of temporal frequency in audition and vision after adaptation to visuo-spatial lateral displacement by prism glasses**

Y Hatada, A R Koene¶ (Institute of Cognitive Neuroscience, Department of Psychology, University College London, 17 Queen Square, London WC1N 3AR, UK; ¶ Department of Psychology, University College London, 26 Bedford Way, London WC1H 0AP, UK; e-mail: y.hatada@psychol.ucl.ac.uk)

Hatada et al’s (2006 *Experimental Brain Research* **169** 417–426) procedure of prism adaptation was modified to increase only the magnitude of ‘visuo-spatial’ shifts right(left)ward and minimised proprioception/motor shifts. The aim was to identify whether a shift in egocentric visual spatial coding by prism adaptation would influence auditory-/visual-egocentric space perception, and auditory-/visual-temporal perception in a specific egocentric space, with specific time course.

Before/after the leftward or rightward shifting prism adaptation, subject's perceived subjective equivalence (PSE) of temporal frequency of 10 Hz was tested by forced-choice (lower/higher frequency) judgment. Stimuli were temporal modification of luminance of a Gaussian gray-scale blob or amplitude of a 3 kHz tone, presented at left/centre/right location for 40 min. Subject's egocentric midsagittal plane was measured by halting a laterally moving visual/auditory stimulus from right/left as it passed in front of the subject. The results showed egocentric 'visuo-spatial' midsagittal judgment shifted right(left)ward after right(left)-shifting adaptation. The average 'auditory-space' midsagittal judgments of two directionalities did not shift. After only right-shifting adaptation, globally both 'visual-temporal' and 'auditory-temporal' frequency PSE shifted toward higher frequency significantly for 20 and 40 min, respectively. Locally, only left hemisphere tests showed significant shifts. Our results suggest the shift in visual-egocentric space shifts temporal-frequency coding beyond vision with time delay.
[Supported by the Gatsby charitable foundation.]

◆ **Audition modulates the temporal resolution of visual events**

T Noesselt, D Bergmann, H-J Heinze, R Fendrich (Department of Neurology II, Otto von Guericke University Magdeburg, Leipziger Strasse 44, D 39120 Magdeburg, Germany; e-mail: toemme@neuro2.med.uni-magdeburg.de)

We investigated whether observer's detection of the brief disappearance of visual stimulus could be improved by concurrent auditory stimulation. In a spatial two-alternative forced-choice design, subjects indicated which of two visual stimuli was briefly blinked off. The moment in time when this blink occurred was marked by either an auditory cue, central visual cue, combined visual and auditory cue, or was not marked by any cue. When the blink was accompanied by a sound burst, there was significant enhancement of subjects' detection ability, relative to the no cue and unimodal visual cue conditions. Control experiments indicated this enhancement was not attributable to an auditory warning effect produced by faster auditory processing: an advance visual cue did not enhance detection performance, and an advance auditory cue decreased the detection advantage. Together, the results indicate that concurrent auditory information can sharpen the temporal resolution of the visual system.

[Supported by DFG SFB-TR31/A8.]

◆ **Hearing faces: A visual influence on voice recognition**

D Robertson, J M Kaufmann, S R Schweinberger (Department of General Psychology, Friedrich Schiller University Jena, Am Steiger 3, D 07743 Jena, Germany; e-mail: David.Robertson@uni-jena.de)

While audiovisual integration is well known in speech perception (McGurk and MacDonald, 1976 *Nature* **264** 746–748), faces and speech are also informative with respect to speaker recognition. To date, audiovisual integration in the recognition of familiar people has never been demonstrated. Here, we show systematic benefits and costs for the recognition of familiar voices when these are combined with time-synchronised articulating faces, of corresponding or noncorresponding speaker identity, respectively. These effects were seen for familiar voices but not for unfamiliar voices, suggesting that they depend on the previous creation of a multimodal representation of a person's identity. Moreover, the effects were reduced or eliminated when voices were combined with the same faces presented as static pictures, demonstrating that the effects do not simply reflect the use of facial identity as a 'cue' for voice recognition. This is the first direct evidence for audiovisual integration in person recognition. We also plan to present initial research on the influence of temporal asynchrony between visual and auditory signals for the perception of speaker identity.

[Supported by a summer studentship by the Nuffield Foundation to DR, and by grant Schw 511/6-1 from the Deutsche Forschungsgemeinschaft to SRS.]

◆ **Detection of inconsistent audio-visual events in virtual reality**

A Sorkin, A Peled¶, D Weinshall§ (Interdisciplinary Center for Neural Computation [§ School of Computer Science and Engineering], Hebrew University of Jerusalem, POB 1255, IL 91904 Jerusalem, Israel; ¶ Rehabilitation Department, Sha'ar Menashe Mental Health Center, Mobil Post Hefer, IL 38814 Hadera, Israel; e-mail: planetz@cs.huji.ac.il)

We investigated the integration of audio-visual events in a detection task. In this task, participants travel in a virtual city viewed through a head-mounted display (HMD) device. While the scene is intended to be as realistic as possible and to resemble our ordinary world, along the way some 50 inconsistencies are inserted in which some object (or objects) are associated with inappropriate sound, colour, or location. Examples for sound inconsistencies include a barking cat, an ambulance emitting sounds typical of an ice-cream truck, or adults who appear to be laughing

Thursday

while making the sound of baby laughter. The participant was required to identify as many such inconsistencies as possible; we measured the detection rate and false alarms. Two groups of subjects were exposed to different sets of sound inconsistencies, where the same visual objects emitted different inconsistent sounds. In one group the inconsistent sound shared some categorical resemblance with the original one, eg an animal emitting the sound of a different animal. In the other group the sound was categorically different, as in an animal emitting the sound of a musical instrument. We found that the first group of categorically similar inconsistent sounds is detected more readily.

◆ **Cross-modal timing capturing with feature-defined saliency**

T Kayahara (Department of Spatial Design and Information Systems, School of Project Design, Miyagi University, 1 Gakuen, Taiwa-cho, Miyagi-ken 981-3298, Japan; Intelligent Modeling Laboratory, University of Tokyo, 2-11-16 Yayoi, Bunkyo-ku 113-8656, Japan; e-mail: kayahara@myu.ac.jp)

It is not easy to bind information from different modalities correctly to perceive coherent world, because the world consists of too many objects and events, and thus mere synchronism could not be used as valid cue for binding information. The cues and the mechanisms for correct integration of information from different modalities remain unclear. I reported an interesting phenomenon suggesting a solution of the problem, in which feature-defined salience of an auditory tone in a tonal sequence captures the perceived timing of visual flash (Kayahara, 2005 *Perception* 34 Supplement, 217). The phenomenon might suggest that the cross-modal binding should occur only between salient or attended information or around an 'anchor' marked by salience. However, in the previous study, the visual stimulus was a single flash on a CRT monitor and its salience was not defined explicitly by features. Therefore, in this study, to manipulate visual salience, a flash sequence with same number of elements as that of the auditory sequence was prepared for visual stimuli, and the perceived timing between salient elements of the visual and the auditory sequence was examined. The relationship between salience in one modality and the perceived timing under various conditions is discussed.

◆ **Cross-modal interaction can modulate face distinctiveness**

I Bühlhoff, F N Newell ¶ (Max-Planck-Institut für biologische Kybernetik, Spemannstrasse 38, D 72076 Tübingen, Germany; ¶ School of Psychology and Institute of Neuroscience, University of Dublin, Trinity College, Dublin 2, Ireland; e-mail: isabelle.buelthoff@tuebingen.mpg.de)

We had shown that memory for a face can be influenced by the distinctiveness of an utterance to which it has been associated (Bühlhoff and Newell, 2004 *Perception* 33 Supplement, 108). Furthermore, recognition of a face can be primed by a paired utterance, suggesting that there is a tight, cross-modal coupling between visual and auditory stimuli and that face distinctiveness can be influenced by cross-modal interaction with auditory stimuli like utterances. When instrumental sounds are used instead of utterances, the perceptual quality of auditory stimuli seemed also to affect memory for faces. Here we further investigated whether instrumental sounds can also prime face recognition. Our results show that this is not the case; arbitrary auditory stimuli do not prime recognition of faces. This suggests that utterances are easier to associate closely with faces than arbitrary sounds. We also investigated whether the observed priming effect of utterances might have been based on the use of different first names in each utterance. We repeated the priming experiment using the same utterances, but name information was removed. A significant priming effect was observed. Thus the semantic information related to the first name is not decisive for the priming effect of utterances on face recognition.

◆ **Cross-modal repetition deficit by a partial report**

M Nakajima (Graduate School of Comprehensive Human Science, University of Tsukuba, 1-1-1 Tennodai, Tsukuba, Ibaraki 305-8572, Japan; e-mail: nakajima@human.tsukuba.ac.jp)

When two successive stimuli with the same phoneme combined in visual-auditory order are presented closely during a rapid serial presentation, people often cannot recognise one of the two stimuli (cross-modal repetition deficit). The purpose of this study was to evaluate which modality of the repeated stimulus is not recognised, with the use of combinations of visual and spoken digits (when presented at a rate of 120 ms per digit). In the experiment, the two successive same digits which were combined in the different modalities were presented. Participants were sometimes asked to recall the digits in either visual or auditory modality (partial-report condition). In the whole-report condition, participants were asked to recall all digits regardless of modality. As a result, participants often could not recall repetitions regardless of both modalities in partial-report condition. Also, cross-modal repetition deficit occurred in both visual-auditory

and auditory – visual order under whole-report condition. Therefore, it is suggested that the cause of the cross-modal repetition deficit are some confounds in memory after completion of phonemic encoding.

◆ **The audiovisual perception of biological motion**

B Schouten, K Verfaillie (Laboratory for Experimental Psychology, University of Leuven, Tienestraat 102, B 3000 Leuven, Belgium; e-mail: ben.schouten@psy.kuleuven.be)

The perception of human actions is frequently studied on 'point-light' figures. This research on the perception of biological motion is traditionally restricted to the visual modality. In contrast, research on multisensory integration specifically concentrates on the interaction of different sensory modalities. A key finding in the latter work is that temporally, spatially, or semantically congruent multimodal stimuli are recognised better and faster than unimodal or incongruent multimodal stimuli. Moreover, the recent discovery of audiovisual mirror neurons in the premotor cortex of the monkey and the finding that visual and auditory information about actions is integrated in the superior temporal sulcus have lead some researchers to conclude that actions may be represented audiovisually. The current research explores two methods to investigate the audiovisual perception of biological motion. The first method investigates to what extent a rhythmic sound can enhance the detection of a visually masked point-light walker by means of an adaptive staircase procedure. The second method assesses the applicability of perturbation analysis to estimate the weights given to the separate sources of action information (auditory and visual) and verifies whether humans integrate audiovisual information about actions in a statistically optimal fashion.

◆ **The recognition of facial expressions in deaf individuals**

M Doucet, F Gosselin, M Lassonde, P G Schyns, N Dupuis-Roy, F Lepore (Département de Psychologie, Université de Montréal, CP 6128, succ. Centre-Ville, Montréal, Québec H3C 3J7, Canada; e-mail: marie-eve.doucet@umontreal.ca)

There is ample evidence that blind people are superior than sighted ones in a number of auditory tasks. In contrast, the only visual task known to exhibit such a superiority in deaf compared to hearing adults is a peripheral-motion-discrimination task. The failure to find other visual processing differences in these two groups might be the result of having compared them on low-level visual abilities rather than real-life visual abilities. We compared the information used by eight deaf individuals to recognise facial expression of emotions with that used by eight matched normal controls by the Bubbles technique. Each subject was submitted to 3072 trials. Each trial consisted in the presentation of one of four faces displaying either happiness or fear, sparsely revealed by randomly located Gaussian holes. Subjects had to discriminate the displayed expressions. The results revealed significant differences between the two groups. Deaf participants used the left visual hemifield, whereas control participants used both hemifields to identify happy faces. Moreover, the deaf individuals used the mouth less than the other participants to identify fearful faces. We interpret these results in light of cross-modal plasticity.

[Supported by Canadian Institutes of Health Research (CIHR).]

◆ **Detection of colour-change of a moving object: Temporal-order judgment**

C Murd[¶], K Kreegipuu[§], J Allik^{¶§} ([¶] Department of Psychology [[§] Estonian Centre of Behavioural and Health Sciences], University of Tartu, Tiigi 78, EE 50410 Tartu, Estonia; e-mail: carolinamurd@hotmail.com)

It has recently been shown in a simple reaction-time experiment that velocity of a moving object may have an accelerating effect on the detection of colour change in the moving object (Kreegipuu et al, 2006 *Vision Research* **46** 1848–1855) which suggests much earlier interaction between motion and colour processing streams than usually thought. To see whether this effect is task-dependent or more universal, we constructed a temporal-order task with an auditory stimulus as a reference for the moving visual stimulus. The subjects were asked to determine the temporal order of the presented auditory stimulus (monotone beep) and the visual stimulus—colour change of the stationary or moving object (5.9 deg s^{-1} or 17.6 deg s^{-1}). Seven values between -225 ms and $+225 \text{ ms}$ were used as a stimulus-onset asynchrony. In temporal-order judgment (TOJ) studies where the auditory stimulus has been compared with the visual stimulus, the auditory stimulus must usually be delayed to be perceived simultaneously with the visual stimulus. It could therefore be assumed that motion would affect TOJs to be more accurate. Although in comparing vision and sound we found converging evidence of the dependence of visual perception on motion velocity, it is possible that the method used is not accurate enough to show a constant/concrete effect of velocity.

Thursday

FACE PERCEPTION◆ **Facial expressions of happiness are identified more quickly in the left visual field**

N Torro-Alves, S S Fukushima[¶], J A Aznar-Casanova (Departament de Psicologia Basica, Facultat de Psicologia, Universitat de Barcelona, passeig de la Vall d'Hebron 171, E 08035 Barcelona, Spain; [¶] FFCLRP – Department of Psychology and Education, University of São Paulo, Ribeirão Preto, avenida Bandeirantes 3900, CEP 14040-901 São Paulo, Brazil; e-mail: nelsonta@usp.br)

The aim of this study was to investigate the pattern of hemispheric dominance in the perception of the facial expressions of happiness. Sixteen undergraduate students (eleven females, five males) took part in the experiment. The divided-visual-field technique was used with the tachistoscopic presentation of two pictures of faces on a computer screen for 150 ms. A happy face could be presented either on the right side or on the left side of the fixation point, while on the opposite side another facial expression was presented simultaneously. In each trial, participants had to determine the side where the happy face was presented. Reaction times were submitted to ANOVAs for repeated measures. Data analysis indicated that happy faces, when paired with neutral and angry faces, were identified more quickly on the left side of the visual field, suggesting a greater involvement of the right hemisphere in the perception of expressions of happiness. These results agree partially with the right-hemisphere hypothesis. There was no difference between judgments by women and men, although an advantage for the identification of expressions of happiness in male faces was observed. This indicates that gender of emotive face influences judgments of participants.

[Supported by CNPq.]

◆ **Underlying dimensionality for age estimations**

N Torro-Alves, J A Aznar-Casanova[¶], S S Fukushima (FFCLRP – Department of Psychology and Education, University of São Paulo, Ribeirão Preto, Avenida Bandeirantes, 3900, CEP 14040-901, Brazil; [¶] Departament de Psicologia Basica, Facultat de Psicologia, Universitat de Barcelona, Passeig de la Vall d'Hebron 171, E 08035 Barcelona, Spain; e-mail: nelsonta@usp.br)

We investigated how different types of wrinkles affect the age estimation mechanism in synthetic (photograph-like) human faces. The software Faces 3.0 was used to generate fifteen faces of both genders: a wrinkle-free face, eight faces presenting only one kind of wrinkle (forehead furrows, eye-lines, nose wrinkle, or mouth wrinkle) and six faces with two, three, or four wrinkles. Half of the wrinkled faces had shallow furrows and the other half deep furrows. Twenty students (mean age = 22.4 years, SD = 2.3 years) participated in making the estimates. Half of them judged male faces and the other half female faces. Pairs of faces were presented on the computer screen and subjects estimated the difference in age between the faces. Pairs of faces were displayed in order to generate a data matrix of dissimilarity (age difference) required to apply an MDS. Two dimensions could explain the dissimilarities: (i) the number of wrinkles, and (ii) the depth of furrows. There were no differences between judgments of the relative age of female and male faces. A differential effect of the types of wrinkles on judgments was observed. Faces with forehead wrinkles and deep furrows were considered more aged than the others.

[Supported by AGAUR(Resolution 18-10-2005, ref. no. 00953).]

◆ **Comparing affective perception in cartoon, schematic and real faces**

Y-H Chang (School of Psychology and Clinical Language Sciences, University of Reading, Harry Pitt Building, Reading RG6 6AL, UK; e-mail: srx03yc@rdg.ac.uk)

Examining various issues in face perception through schematic faces, many researchers implied that simple schematic faces might have similar effects to those of real faces. Nonetheless, whether people have similar processing for different types of facial emotions is still unknown. To prove that people have similar emotional processing for different types of facial expressions, three types of schematic faces were used to analyse this. In experiment 1, simple schematic faces came from three types of curves that represent three categories of eyes (happy, neutral, and sad), each of which was crossed with three types of mouths (happy, neutral, and sad). The result demonstrated that, upon perceiving facial expression, participants were more likely to put their judgments on the emotion a particular mouth was expressing. In experiment 2, another similar task was conducted with more realistic faces. Again, it came to the same result that the emotion of mouths dominated participants' perception of facial expressions. In experiment 3, similar task was conducted with photographs of real faces, and similar result was found. Accordingly, the conclusion is that people process schematic faces and real faces in a similar manner.

◆ **Pulling faces from an evolutionary perspective**

A K Dunn, H Mustard (Division of Psychology, School of Social Sciences, Nottingham Trent University, Burton Street, Nottingham NG1 4BU, UK; e-mail: andrew.dunn@ntu.ac.uk)

The human face is information-rich, providing amongst other things clues to health and fertility. We explored what happens to perceived (long/short term) attractiveness and health when faces are presented with one of three types of facial distortion: genetic (eye enlargement), accident (scar across one eye), and eye-patch (distortion control). Thirty participants (fifteen male and fifteen female) provided Likert attractiveness and health ratings for fifteen opposite-sex head-shoulder photographs. It was predicted that all three distortions should have a negative affect on face ratings owing to an overall increase in facial asymmetry. It was further predicted that the putative genetic disfigurement should have a more powerful effect on rating, since, from an evolutionary point of view, genetically based distortions should indicate greater threat to the gene pool than acquired distortions. Consistent with expectations, all three distortions reduced perceived attractiveness and health relative to baseline. The accident and the genetic distortion faces were significantly less attractive than the eye-patch faces (though there was no difference between them). However, there was a significant decrease in perceived health for the genetic distortion relative to the accident and eye-patch conditions, and hence support for our second hypothesis in relation to perceived health.

◆ **Bias in high-level aftereffects induced by dynamic facial expressions**

T Jellema, M Hudson (Department of Psychology, University of Hull, Cottingham Road, Hull HU6 7RX, UK; e-mail: T.Jellema@hull.ac.uk)

It is almost impossible to look at a human face and not get some notion about the mental or emotional state of its owner. We investigated possible biases in the attribution of mental states by presenting video clips of dynamic facial expressions. Each face started with a happy or angry expression, which gradually changed to a neutral expression. Participants had to judge the emotion displayed by the neutral face on a 5-point scale, ranging from slightly happy, via truly neutral, to slightly angry. The amount of geometrical change between happy and neutral faces was identical to that between angry and neutral faces. The results showed a significant asymmetry between the two conditions: the participants judged the neutral face to be slightly angry in the happy-to-neutral condition, while the identical neutral face was judged to be truly neutral in the angry-to-neutral condition. We discuss the results within a theory-of-mind context, and suggest that a cost-benefit analysis may have resulted in a bias towards attributing negative states of mind, as the cost of falsely attributing a negative state is likely to be less than the cost of failing to attribute one.

◆ **Investigation of the speciality of surprise by means of adaptation to the facial expressions of emotion**

S Shibui, H Yamada¶ (Faculty of University Evaluation and Research, National Institution for Academic Degrees and University Evaluation, 1-29-1, Gakuen-nishimachi, Kodaira-shi, Tokyo 187-8587, Japan; ¶ Department of Psychology, College of Humanities and Sciences, Nihon University, 3-25-40, Sakurajosui, Setagaya-ku, Tokyo 156-8550, Japan; e-mail: shibui@niad.ac.jp)

In our previous study (Shibui et al, 2003 *Perception* 32 Supplement, 173) we suggested the existence of adaptation to facial expressions as well as face identification. In this study, we investigated whether adaptation to facial expressions could exist in each of the six basic facial expressions (happiness, anger, sadness, surprise, fear, disgust). We created intermediate faces using the morphing technique (100%—original, eg happy), 75%, 50%, 25%, (0%—neutral), for each expression. Participants performed dimensional rating and categorical rating task in experiment 1. In experiment 2, participants judged the expressions of test faces exposed for 200 ms following 5 s viewing of an adaptation face in six alternative forced-choice tasks. In the control condition, subject judged only test faces. The effects of adaptation were represented by delayed reaction times between the control condition and the condition with adaptation faces. Effects of adaptation to the surprise face were not explained by either dimensional or categorical distance, whereas other expressions were explained. Researchers have suggested that surprise is not an emotion but a cognitive state before moving to another emotion. Our result may reflect this explanation.

◆ **Using 3-D human-monkey morphs to explore the boundaries of species dependent face-categories in humans**

R Sigala, A Koch, K J Nielsen, N K Logothetis, G Rainer (Max Planck Institute for Biological Cybernetics, Department of Physiology of Cognitive Processes, Spemannstrasse 38, D 72076 Tübingen, Germany; e-mail: rodrigo.sigala@tuebingen.mpg.de)

Face perception has often been investigated with human faces differing in categories such as race or gender. Here, we investigate the perceptual border across species. We applied a method

Thursday

based on support vector machines to generate images of hybrid monkey – human faces ('morphs') with different levels of human contribution. In the 'explicit' experiment, we asked subjects to rate morphs at different morph levels as 'humans' or 'monkeys'. We found that subjects rated the morphs as humans when they had a human contribution of at least $56\% \pm 3\%$. In the 'implicit' experiment, we asked whether subjects could distinguish between successively presented morphs differing by $\pm 10\%$ morph level from a morph centre. By varying the morph centre value from 10% to 90%, we were able to measure subject's sensitivity to detect species differences along the human – monkey continuum. We found that the sensitivity of subjects to detect species differences was highest when morphs had a human contribution of $65\% \pm 3\%$. In summary, the human – monkey boundary does not lie at the midpoint of the human – monkey continuum, but tends to be shifted towards the human side. Our results reveal an asymmetry in the perception of human – monkey morphed faces, which may be species-specific and/or due to expertise. [Supported by the Max Planck Society]

- ◆ **Fractal dimensions of the structure of facial affect perception in two stimulus durations**
T Takehara, F Ochiai¶, H Watanabe§, N Suzuki# (Department of Psychology, Hokusei Gakuen University, 2-3-1 Oyachi-nishi, Atsubetsu-ku, Sapporo 004-8631, Japan; ¶ Department of Modern Life, Tezukayama University, 3-1-3 Gakuen-minami, Nara 631-8585, Japan; § National Institute of Advanced Industrial Science and Technology, 1-8-31 Midorigaoka, Ikeda 563-8577, Japan; # Department of Psychology, Doshisha University, Karasuma-Imadegawa, Kamigyo-ku, Kyoto 602-8580, Japan; e-mail: takehara@hokusei.ac.jp)

The structure of facial affect perception was found to have a fractal property that was characterised in terms of a fractional fractal dimension. Moreover, the internal structure of facial affect perception was also found to have a fractal property. We manipulated the stimulus duration that appeared to influence the facial affect perception system and set two durations (100 ms and 3000 ms) as independent variables. We presented some prototypical and morphed facial images to twenty-four participants and asked them to rate the facial stimuli on an affect grid that consisted of 'valence' and 'arousal' as the axes. Measuring the total length of the perimeter, we calculated the fractal dimensions and submitted them to a *t*-test with the two stimulus durations as a within-participant factor. We found the stimulus durations to be significant ($t_{23} = 2.12, p < 0.05$). In other words, a fractal dimension of 1.41 in 100 ms was significantly higher than that of 1.33 in 3000 ms. The difference in the fractal dimensions between 100 ms and 3000 ms reflects the qualitative difference in the structure of facial affect perception.

- ◆ **Inducing opposite aftereffects for ¾ and front views of faces**
L L M Welling, L M DeBruine¶, P E G Bestelmeyer, A C Little§, B C Jones (School of Psychology, University of Aberdeen, William Guild Building, Aberdeen AB24 2UB, Scotland, UK; ¶ School of Psychology, University of St Andrews, St Andrews KY16 9JU, Scotland, UK; § School of Biological Sciences, University of Liverpool, Crown Street, Liverpool L69 7ZB, UK; e-mail: l.welling@abdn.ac.uk)

Although electrophysiological and neuroimaging studies have revealed different populations that are broadly tuned to different views of faces, it is unclear if these neurons code aspects of face shape or code only head position or gaze direction. Some studies based on face aftereffects have interpreted the generalisability of aftereffects across different viewpoints as evidence for viewpoint-invariant coding of face shape. Others, however, have interpreted a significant reduction in the magnitude of aftereffects when generalising across viewpoints, and opponent aftereffects for mirror-reversed ¾ views, as evidence for viewpoint-dependent coding of face shape. Here we show that it is possible to simultaneously induce opposite aftereffects for ¾ left and front views of faces with manipulated mouth position. For example, simultaneous adaptation to ¾ left views with raised mouth position and front views with lowered mouth position caused raised mouth position to appear more normal for ¾ left views of novel faces, but less normal for front views. Furthermore, adaptation to ¾ left views with raised mouth position caused lowered mouth position to appear more normal in ¾ right views. These findings suggest that there are neural populations that are tuned to optimally respond to viewpoint-specific aspects of face shape.

- ◆ **Role of experimental factors in sex categorisation of faces**
E Nikitina (Institute of Psychology, Russian Academy of Sciences, Yaroslavskaya 13, 129366 Moscow, Russia; e-mail: e.nikitina@psychol.ras.ru)

Sex categorisation of faces is known to be a very effective process the accuracy of which exceeds 95% for the images of adults. But in difficult cases (for example, categorisation of babies' faces) the influence of experimental factors can be significant. We used photo images of newborns, 7-year-old children, 20-year-old students, and video fragments of newborns as stimuli. All persons

represented on the stimuli were unfamiliar to the observers. The experiment with newborns' photo and video images showed that sex was discriminated better by static images. Dynamic presentation of faces produced a lot of extra information, which broke female/male face prototypes and complicated discrimination. The role of a frame around a face was studied in the experiment with images of 7-year-old children. We compared the categorisation of sex in two sets of photos: with the ears hidden by a frame and with visible ears. A visible ear zone was found to be a strong masculinising factor of a face. The hypothesis about the influence of a face direction, which was studied with two sets of photos of 20-year olds (faces turned $\frac{3}{4}$ to the right or to the left) has not been found to be true.

◆ **Reading and discrimination of various facial expressions**

S Park, K Cho[¶], M Chung[§], H Ghim (Department of Psychology, College of Social Science, Chungbuk National University, Gaesin-dong, Heungduk-gu, Cheongju, Chungbuk 361-763, Korea; [¶] Center for Cognitive Science, Yonsei University, Sinchon-dong, Seodaemun-gu, Seoul 120-749, Korea; [§] Department of Social Welfare & Psychology, Kkottongnae Hyundo University of Social Welfare, 387 Sangsam-ri, Hyundo-myon, Chongwon-gun, Chungbuk, Korea; e-mail: happyalo@gmail.com)

Previous studies of facial discrimination have been limited to basic emotions. This study made use of a broad range of emotional faces and words (36 words and facial expressions) which more accurately represent real-world stimuli. In experiment 1, a facial expression was presented with four words: (i) a corresponding word for the facial expression; (ii) the farthest word on 2-D emotional space; (iii) a word near to $\frac{1}{3}$ of distance between (i) and (ii); (iv) a word near to $\frac{2}{3}$ of the distance between (i) and (ii). The participants' task was to select a word that best describes emotion of the displayed face. High correct response ratios were found for facial expressions 'surprised' or 'joyful', but low for 'shy' or 'earnest'. In experiment 2, a word was presented with four facial expressions. The results were similar to experiment 1: high ratios were recorded for 'surprised' or 'joyful', but low for 'undeserved'. It is confirmed that finding the appropriate facial expression or word among various expressions or words is easy in the case of basic emotions. It might be not difficult to find emotional states like 'sleepy' or 'collapsed' though they are low arousal states, and it means that the second dimension is an important dimension of emotion. [Supported by a Korea Research Foundation Grant funded by the Korea Government (MOEHRD, Basic Research Promotion Fund; KRF-2005-079-HM0004).]

◆ **Face-pair scrutiny—subject-type classification**

G J Brelstaff, L Brodo[¶], M Bicego[§], E Grosso[§] (CRS4, Parco Scientifico e Tecnologico 'Polaris', Ed.1, CP 25, I 09010 Pula, Italy; [¶] DSL, Facoltà di Lingue e Letterature Straniere [§ DEIR], University of Sassari, via Torre Tonda 34, I 07100 Sassari, Italy; e-mail: gjb@crs4.it)

Forensic, security, and health-care processes defer to human observers when identifying visual differences beyond a certain degree of subtlety. For identikit, or passport-like, controls this typically involves extensive scrutiny of face-pair images. We tested forty-nine naive subjects to examine how they would mark differences seen between face pairs. In each trial, one pair of face images was displayed, side-by-side, for 20 s while the subjects marked where they saw differences by clicking the mouse within the right-hand image. The face pairs were specially selected from the BANCA image archive to best represent a wide variety of degrees of difference. Here, we report only trials involving two face pairs: a very difficult, and a very easy to distinguish face pair. From the result we are, nevertheless, able to classify participants into distinct sets of subject types by a parametric analysis of the temporal and spatial characteristics of each individual's click-trail. A graphical presentation of the analysis and classification is available. Although provisional, this classification might prove useful for assessing candidate scrutinisers for real-world tasks.

◆ **Adaptation of familiar and unfamiliar faces**

P J B Hancock, A L Hogg, A H McIntyre (Department of Psychology, University of Stirling, Stirling FK9 4LA, Scotland, UK; e-mail: pjbh1@stir.ac.uk)

Face adaptation has been shown to operate at a number of levels, including identity-specific, sex-specific, and faces generally. We studied the interaction between adaptation to familiar and unfamiliar faces, by varying the separation of the eyes, adapting to either very wide or very narrow and testing choice between mildly wide or narrow. In experiment 1, we used the same set of face images (ie variations on the same photographs) for adaptation and test. Adaptation to familiar faces produced a strong effect for those faces at test but very little transfer to other faces. Adaptation to unfamiliar faces produced a similar, moderate effect on all test faces: the familiar ones, and both studied and new unfamiliar faces. There was thus a marked asymmetry between the effects of studying modified familiar and unfamiliar faces. In experiment 2, we used

Thursday

different images of the same individuals at adaptation and test. Now adaptation to both familiar and unfamiliar faces produced similar, moderate effects on all faces at test. This is consistent with a model where a global average face can be adapted by viewing any distorted faces; but where there is already a representation for a face, this can be updated by addition of a new exemplar.

◆ **The eye movement strategies performed during a face-matching task**

C Havard, M Burton (Department of Psychology, University of Glasgow, 58 Hillhead Street, Glasgow G12 8QB, Scotland, UK; e-mail: catriona@psy.gla.ac.uk)

How do we look at a pair of faces when we try to determine whether they belong to the same person? Previous research on a matching task showed that internal features received significantly more eye gaze than the external features (Stacey et al, 2005 *British Journal of Psychology* 96 407–422). However, what internal features are important when conducting a face matching decision? We carried out three face matching experiments and manipulated face orientation, the distance between the two faces, and the spatial frequency of the images. We found that for all conditions the eyes were the most important features, and received more eye gaze than any of the other features. A scanning strategy was observed whereby the eyes that were in the centre of the screen (the right eye on the left face, and left eye on the right face) received more gaze than the eyes that were to the outer sides of the screen. These studies appear to show that viewers can accurately make a face matching decision by fixating upon a single eye of each face, and do not need to fixate on the other features.

◆ **Body motion influences the processing of identity**

K S Pilz, Q C Vuong¶, H H Bülthoff, I M Thornton§ (¶ Department of Cognitive and Computational Psychophysics] Max Planck Institute for Biological Cybernetics, Spemannstrasse 38, D 72076 Tübingen, Germany; § Department of Psychology, University of Wales Swansea, Singleton Park, Swansea SA2 8PP, Wales, UK; e-mail: karin.pilz@tuebingen.mpg.de)

We investigated how body motion might influence the recognition of facial identity. Two heads from the MPI face database were attached to the same 3-D body model. These avatars were then animated with two different sequences of karate motions, one performed by a professional (A) and the other by an amateur (B). In a learning stage, observers ($N = 16$) were trained to recognise these two animated figures. Test stimuli were created by morphing the learned heads in 10% steps from 0% (head A) to 100% (head B). Note that the 50% morph head is completely ambiguous. Each head was then attached to the same body and animated with motion sequences associated with either A or B. At test, observers were shown motion segments and had to decide whether the face looked more like A or B. Fitted psychometric functions were used to determine the 50% threshold. Observers consistently rated the 50% morphed head as avatar A when it was animated with A's motion and as avatar B when it was animated with B's motion. These results suggest that an observers' ability to determine the facial identity of an avatar can be biased by the way that avatar moves.

◆ **Face adaptation effects: When stable representations are quite flexible**

C-C Carbon (Department of Psychological Basic Research, Faculty of Psychology, University of Vienna, Liebiggasse 5, A 1010 Vienna, Austria; e-mail: ccc@experimental-psychology.com)

It is commonly accepted that face representations are quite stable in order to ensure fast and accurate recognition. However, as discussed by Carbon and Leder (2005 *Advances in Cognitive Psychology* 1 1–7), face representation must also be flexible enough to be up-to-date. Only a flexible mechanism allows optimised face recognition as faces undergo both rigid and non-rigid changes over time. By employing a face-adaptation procedure during which participants were exposed to distorted versions of familiar faces we could show that the subsequent recognition of these faces was strongly biased towards the inspected distorted versions. This adaptation effect could even be shown for a delay of 24 h between inspection and test phase. Moreover, adaptation occurred in an identity-specific way, including same pictorial and alternative versions of the previously inspected face. The temporal stability and the identity specificity of the effect indicate that this kind of adaptation has not only a perceptual basis but affects representation as well.

◆ **Gaze direction influences perceptions of facial expressions and face preferences**

C A Conway, L M DeBruine¶, B C Jones (School of Psychology, William Guild Building, University of Aberdeen, Aberdeen AB24 2UB, Scotland, UK; ¶ School of Psychology, University of St Andrews, St Mary's Quad, St Andrews KY16 9JU, Scotland, UK; e-mail: c.conway@abdn.ac.uk)

Most studies of expression perception and face preferences have used face stimuli with direct gaze. Here, however, we show that gaze direction alters both the perceived intensity of facial expressions

and the strength of preferences for feminine female faces. While direct gaze increased the perceived intensity of anger, fearful faces tended to be perceived as more fearful with averted gaze than direct gaze (experiment 1). Direct gaze also increased the perceived intensity of happiness, while sad faces were perceived as more sad with averted gaze than direct gaze (experiment 2). Finally, preferences for feminine female faces were stronger when the faces were shown with direct gaze than when the faces were shown with averted gaze (experiment 3). While our findings for intensity of expressions indicate that changing gaze direction can alter perceptions of emotional expressions, the effect of gaze direction on face preferences indicates that attraction is not only influenced by the physical beauty of others but also by the direction of their attention. Collectively, these findings show that people integrate information from different physical and social cues when perceiving faces and demonstrate the complexity and sophistication of the mechanisms and processes that underpin face perception.

◆ **Perception of smiling faces with deformed facial feature**

K Masame, H Ishi¶, T Adachi§, S Kouchi# (School of Nursing, Miyagi University, 1 Gakuen, Taiwa-cho, Kurokawa-gun, Miyagi 981-8267, Japan; ¶ Miyagi National College of Technology, 48 Nodayama, Medeshima-Shiote, Natori-shi, Miyagi 981-1239, Japan; §Department of Developmental and Clinical Studies, Miyagi Gakuin Women's College, 9-1-1 Sakuragaoka, Aoba-ku, Sendai 981-8557, Japan; #Clinics of Maxillo-Oral Disorders, Tohoku University Dental Hospital, 4-1 Seiryō, Aoba-ku, Sendai 980-8577, Japan; e-mail: masame@myu.ac.jp)

People with deformed faces often show suppressive facial expressions. These cause many interpersonal problems. Two experiments were carried out to examine whether the facial deformity influences the efficiency of the perception of smiling faces. In the first experiment we checked discrimination between smiling and neutral faces using cleft-lip-and-palate (CLP) faces and normal ones. CLP faces had deformed nose and scar of upper lip. Participants were fifteen female undergraduates. There were three presentation conditions: whole faces, upper half of ones, and lower half of ones. The results showed there was almost no difference of responses between CLP faces and normal ones. For both CLP and normal faces, the responses to upper half of faces were significantly longer than the ones for whole faces and lower half of faces. In the second experiment, with the same task, the stimulus faces had a 20% horizontally enlarged right eye and/or right side of lip. Participants were fifteen undergraduates. The results showed that the 20% enlarged eye and/or lip had no influence on discrimination between smiling and neutral faces. We conclude that the perception of smiling faces is relatively immune to the deformity of facial features.

◆ **Attention to faces is modulated by race**

R Caldara, M Bindemann (Department of Psychology, University of Glasgow, 58 Hillhead Street, Glasgow G12 8QB, Scotland, UK; e-mail: r.caldara@psy.gla.ac.uk)

Faces engage and retain visual attention more strongly than other stimuli. Yet, it has been demonstrated that efficiency in face processing is modulated by race, a perceptual phenomenon often referred to as the 'other-race effect'. Other-race faces are recognised less accurately than same-race faces, but are classified faster by race. However, it is still unknown whether race also influences the allocation of attention to faces. In a first experiment, observers responded to a lateralised target probe, which could appear in the location of a preceding equiluminant object cue (pictures of homogenous houses) or a competing face cue (Caucasian and Asian faces). In a second experiment, the target probe consisted of a fixation cross, which changed colour (red or green) after a short temporal delay and was superimposed onto a solitary centrally presented cue (houses, Caucasian or Asian faces). Both experiments produced an attentional bias for faces, but, crucially, this varied as a function of task and of the input race. These findings are discussed in relation to existing research on faces and attention, providing new insights into the framework of the other-race effect.

◆ **Face aftereffects reveal interdependent processing of expressions and sex**

B C Jones, P E G Bestelmeyer, L M DeBruine¶, A C Little§, A Schneider, L L M Welling, C A Conway (School of Psychology, University of Aberdeen, William Guild Building, Aberdeen AB24 2UB, Scotland, UK; ¶ School of Psychology, University of St Andrews, St Mary's Quad, St Andrews KY16 9JU, Scotland, UK; § School of Biological Sciences, University of Liverpool, Crown Street, Liverpool L69 7ZB, UK; e-mail: ben.jones@abdn.ac.uk)

Prominent models of face processing have emphasised the functional and neurological independence of the systems that process invariant facial characteristics (eg sex, identity) and facial expressions. Using a visual-adaptation paradigm, we demonstrate that expression aftereffects,

Thursday

whereby exposure to an expression decreases sensitivity to that expression, can be simultaneously induced in opposite directions for male and female faces. For example, simultaneous adaptation to angry male faces and fearful female faces decreased sensitivity to anger in male faces and fear in female faces (experiment 1). These sex-contingent expression aftereffects could not be explained by sex differences in expression production (experiment 2). Furthermore, sex-contingent adaptation occurred between sex categories but did not occur when equivalent shape differences among adapting faces were within a sex category (experiment 3). This demonstrates that expressions and the invariant characteristic of face sex are processed by interdependent, rather than independent, systems and reveals a mechanism for integrating information from physical characteristics in faces and social signals during social interactions.

◆ **The role of exploratory action in face encoding**

C H Liu, J Ward¶, H Markall (Department of Psychology [¶ Department of Computer Science], University of Hull, Hull HU6 7RX, UK; e-mail: c.h.liu@hull.ac.uk)

Research on face recognition has mainly relied on methods where observers are relatively passive viewers of face stimuli. We investigated whether active exploration of 3-D face stimuli could facilitate recognition performance. A yoked design was employed in a series of experiments where the task either required old/new recognition memory decisions or matching two sequentially displayed face stimuli. Observers in the active condition explored 3-D views of faces via a joystick during training, whereas observers in the passive condition simply viewed the replay of the same sequence of face stimuli generated by the active observers. We found that the active condition produced better recognition and matching performance than the passive condition. Results of an experiment where 3-D faces were substituted by 3-D chair stimuli suggest that active exploration may play a more prominent role in face recognition than within-category object recognition. The study provides the first evidence that active exploration of face stimuli can lead to better recognition memory and matching accuracy. It suggests that face encoding may involve a tacit sampling strategy assisted by bodily actions.

[Supported by the British Academy]

◆ **Recognition of emotion in moving and static composite faces**

A Schwaninger, M Kleiner, S Chiller-Glaus, F Hofer, B Knappmeyer¶ (Max Planck Institute for Biological Cybernetics, Department Bülthoff, Spemannstrasse 38, D 72076 Tübingen, Germany; ¶ Center for Neural Science/Psychology, New York University, 6 Washington Place, New York, NY 10003, USA; e-mail: adrian.schwaninger@tuebingen.mpg.de)

We investigated the role of holistic processing for the perception of facial emotion and its interaction with non-rigid motion. Using an experimental paradigm by Young et al reported in 1987, we tested recognition performance of aligned and misaligned composite faces with six basic emotions (happiness, fear, disgust, surprise, anger, sadness). Stimuli were shown as 3-D animated realistic video sequences (moving condition) and as static peak expressions (static condition). The results ($N = 24$) revealed that misaligned composites were better recognised than aligned composites, both for static and moving stimuli. When the two halves were aligned, a new emotion resembling each of the two originals seemed to emerge, suggesting holistic processing. This made it very difficult to identify the emotions from either half. When the top and bottom halves were misaligned horizontally (impairment of holistic processing), the two halves did fuse significantly less to create a new emotion, and the constituent halves remained identifiable. Whereas moving stimuli were better recognised than static faces, there was no interaction between motion and alignment. These results indicate that facial-expression processing is holistic in static and moving faces to a similar degree.

[Supported by a grant from the European Commission in the 5th Framework COGVIS project (IST-2000-29375).]

◆ **Temporal mislocalisation of changing objects is modulated by the processing type**

M Sajjadi, M Sanayei¶ (Neuroscience Research Group, School of Medicine, Isfahan University of Medical Sciences, Isfahan, Iran; ¶ Neuroscience Research Group, Talented Students Office, Medical Education Development Center, Isfahan University of Medical Sciences, PO Box 81745/353, Hezar Jarib Street, Isfahan, Iran; e-mail: mahmoud_sajjadi64@yahoo.co.uk)

The tendency of briefly flashed stimuli to appear to lag behind the spatial position of physically aligned moving stimuli is known as the flash-lag effect. We investigated whether the same effect exists when changes occur in the domain of facial features rather than space position. We changed the distance between two eyes in a front view of a face and presented the images sequentially resembling a gradual increase/decrease of the eye distance in time (29 frames \times 70 ms). We asked

subjects to judge whether their perceived frame was ahead/before in time compared to another frame flashed during sequential presentation beside it. A constant-stimulus method was used to measure the magnitude of perceptual shift in time by changing the offset between frames of flash and target stimuli. Subjects reported that the perceived stimulus was 180 ms ahead of the real presented stimulus ($p < 0.05$, one-sample t -test). This shift was significantly smaller ($p < 0.05$, paired t -test) when targets and flashes were inverted (135 ms). It has been shown before that our visual system processes upright faces in a more configural manner than inverted ones. Our result shows that mislocalisation of objects in time domain is modulated by its type of processing. [Supported by Talented Student Office, Medical Education Development Center, Isfahan University of Medical Science.]

LIGHTNESS, BRIGHTNESS, TRANSPARENCY

◆ **Binocular lustre as an attribute of surface perception**

M A Formankiewicz, J D Mollon ¶ (Department of Optometry and Ophthalmic Dispensing, Anglia Ruskin University, East Road, Cambridge CB1 1PT, UK; also ¶ Department of Experimental Psychology, University of Cambridge, Downing Street, Cambridge CB2 3EB, UK; e-mail: monikafor@cantab.net)

Discrepant monocular luminances can lead to a percept that has been discussed in the context of binocular rivalry: binocular lustre [eg Levelt, 1965 *On Binocular Rivalry* (Assen: Van Gorcum)]. However, the lateral separation of the two eyes means that this discrepancy in monocular luminance levels could also arise when viewing a glossy surface, which reflects more light in one direction than in others. We used a visual-search task to determine the rules that govern the detection of binocular lustre. Distractors were chosen to ensure that the only consistent cue was that of discrepant monocular luminances. We found that thresholds were determined by the ratio of the two monocular luminance contrasts and were affected by target size and presentation time. Therefore the behaviour of binocular lustre at threshold is similar to that of other visual attributes: it is determined by luminance contrast and not luminance; and it also shows a significant level of temporal and spatial summation. We conclude that binocular lustre should be considered as an important attribute of surface perception and not just as a by-product of binocular rivalry.

[Supported by the Cambridge Commonwealth Trust, Gonville and Caius College.]

◆ **Dark surrounds restrict the lightness constancy for increments under glare conditions**

E M Colombo, L A Issolio, P A Barrionuevo (Department of Lighting, Light and Vision, Faculty of Science and Technology, National University of Tucumán, Avenida Independencia 1800, CP 4000, San Miguel de Tucumán, Argentina; e-mail: ecolombo@herrera.unt.edu.ar)

When the perceived brightness of a decrement in luminance is investigated under conditions of transient glare, almost perfect lightness constancy is found (Issolio and Colombo, 2006 *Perception & Psychophysics* in press). Here, we investigated the effect of transient glare on the perceived brightness of increments. In order to obtain the matching luminance (L_m), two subjects compared the brightness of a foveal test patch without glare to the brightness of the standard patch with glare. The glare was produced by a source 10° from the fovea (30 and 60 lx). The standard stimuli (L_{std}) were increments of 0.5 cd m^{-2} . The experiment was performed with different surrounds (L_s) between 0.01 and 0.4 cd m^{-2} . L_m/L_s deviates from the lightness constancy prediction, tending towards the ratio match prediction for the darkest surrounds. This result could be due to a trade-off between two processes. First, glare produces a compression while the dark surround sets a 'black limit'—a low-level process. Second, the visual system intends to discount the veiling luminance to achieve lightness invariance—a high-level process.

[Supported by E345/1 CIUNT—PIP 5013 CONICET—PICT 13-15190 ANPCyT.]

◆ **Material appearances under minimal stimulus conditions: Lustrous and glassy qualities**

R Mausfeld, G Wendt (Institute for Psychology, University of Kiel, D 24098 Kiel, Germany; e-mail: mausfeld@psychologie.uni-kiel.de)

The perception of material qualities of objects and stuff can be regarded as a central task of the visual system (Adelson, 2001 *Proceedings of the SPIE* **4299** 1–12), which apparently contains a rich set of primitives for material qualities. While most material appearances can only be triggered by complex combinations of input parameters (such as luminance distributions and texture statistics), glassy and lustrous appearances can be observed under highly impoverished stimulus conditions (eg no texture or specular highlights), as indicated by Helmholtz's stereoscopic lustre or Anstis's monocular lustre from flicker (Anstis, 2000 *Vision Research* **40** 2551–2556).

Thursday

In our forced-choice experiments, we employed (i) haploscopically superimposed achromatic centre-surround configurations in which the luminance of the centre patch was temporally modulated, and (ii) monocular presentations of three adjacent faces of a rotating dodecahedron, whose luminances were independently temporally modulated. Contrary to previous interpretations, we found for centre-surround configurations contrast reversal (either across eyes or over time) not to be a relevant parameter but rather the 'phase difference' between the eyes as well as the steepness of the temporal gradients.

[Supported by Grant MA 1025/10-1 from Deutsche Forschungsgemeinschaft.]

◆ **Lightness contrast modulated by transparency perception**

S Takahashi (Department of Psychology, Graduate School of Environmental Studies, Nagoya University, Furo-cho, Chikusa-ku, Nagoya 464-8601, Japan; e-mail: shinya@lit.nagoya-u.ac.jp)

A new phenomenon in which the magnitude of lightness contrast is modulated by transparency perception is presented. Two gray patches with equal reflectance (TFs) were put on (i) black and white fields [high-contrast (H-C) condition], (ii) darker-than-TF gray and lighter-than-TF gray fields [low-contrast (L-C) condition], (iii) the same fields as L-C condition with much-darker-than-TF gray and much-lighter-than-TF gray large fields surrounding them so that inner inducing fields could be perceived as a transparent surface [transparency (T) condition], and (iv) the same configuration as T condition except that a white line was added to separate inner and outer inducing fields aimed at preventing transparency perception [deteriorated transparency (D-T) condition]. Eighty-five observers reported, by matching method, the perceived lightness of two patches in each condition. The magnitude of lightness contrast was found to be larger in T condition than in D-T condition, and larger in D-T condition than in L-C condition, though the inner inducing fields enclosing TFs were the same in these conditions. Stronger lightness contrast in T condition was assumed to be induced by the outer, much-darker and much-lighter, inducing fields rather than the inner ones which were perceptually 'neglected' as a transparent surface overlapping the configuration.

◆ **Seeing brightness and darkness: More dimensions than meet the eye?**

T Vladusich, M P Lucassen¶, F W Cornelissen (Laboratory for Experimental Ophthalmology, BCN Neuro-imaging Center, School of Behavioural and Cognitive Neurosciences, University Medical Center Groningen, University of Groningen, PO Box 30.001, NL 9700 RB Groningen, The Netherlands; ¶ Department of Human Interfaces, TNO Human Factors, PO Box 23, NL 3769 ZG Soesterberg, The Netherlands; e-mail: t.vladusich@med.umcg.nl)

Classical theories of achromatic colour perception assume that bright and dark constitute the endpoints of a continuum containing all possible shades of grey. We tested this assumption using visual stimuli in which both brightness and darkness were simultaneously induced into a target surface. According to classical theories, the brightness and darkness components should partially cancel and subjects should always be able to make satisfactory achromatic colour matches in a comparison surface. We show that, contrary to this prediction, subjects have greater difficulty setting satisfactory matches when brightness and darkness components are simultaneously induced into a target surface than when only one or the other component is induced. Our results can be understood by assuming that all grey shades constitute points in a two-dimensional achromatic colour space whose underlying dimensions correspond to brightness and darkness. This theory predicts that subjects cannot make satisfactory matches across two displays differing only in the variance of induced brightness and darkness components.

[Supported by Grant 051.02.080 of the Cognition program of the Netherlands Organization for Scientific Research (NWO).]

◆ **Achromatic McCollough effect is activated by stimulus luminance**

D Janelidze, I Intskirveli, M Roinishvili, K Parkosadze, G Chichua, A Kezeli (Laboratory of Vision Physiology, I Beritashvili Institute of Physiology, Georgian Academy of Sciences, Gotua 14, 0160 Tbilisi, Georgia; e-mail: david.janelidze@gmail.com)

It has been shown that chromatic McCollough effect (ME) is wavelength-contingent (Thompson and Latchford, 1986 *Nature* **320** 525–526). It is also known that chromatic and achromatic information processing mechanisms significantly differ from each other. It was interesting to find out if the regularities established during chromatic ME are justified in the case of achromatic ME. Experiments were performed on twelve human subjects. Observers were sequentially presented with vertical black-and-white and horizontal black-and-gray gratings. A combined grating, consisting of horizontal and vertical black-and-white stripes was used as test stimulus. During adaptation procedure, illumination was adjusted in such a way that gray and white stripes of adaptation stimuli had different luminance in one case, while in the other case the luminance

was the same. Achromatic ME worked only in the first case, indicating that achromatic ME depends on the difference of luminance of white and gray stripes of adaptation stimuli. Therefore acquisition of achromatic as well as chromatic ME is activated by physical parameters at the input of visual system, which the latter uses for construction of the subjective parameters. [Supported by the Volkswagen Foundation.]

◆ **Achromatic colour matching with different contrast polarities and magnitudes: Experiments and modeling**

M P Lucassen, F W Cornelissen¶, E L Tiggelaar§, T Vladusich¶ (Department of Human Interfaces, TNO Human Factors, PO Box 23, NL 3769 ZG Soesterberg, The Netherlands; ¶Laboratory for Experimental Ophthalmology, BCN Neuro-imaging Center, School of Behavioural and Cognitive Neurosciences, University Medical Center Groningen, University of Groningen, PO Box 30.001, NL 9700 RB Groningen, The Netherlands; §Department of Cognitive Psychology, Vrije Universiteit, Van der Boechorststraat 1, NL 1081 BT Amsterdam, The Netherlands; e-mail: marcel.lucassen@tno.nl)

We conducted experiments to examine how the visual system integrates edge information to encode surface brightness. Subjects set the luminance of a test disk to appear the same brightness as a reference disk surrounded by a ring on a common background. We varied the contrast polarities and magnitudes of inner and outer edges in the disk–ring configuration. Our main new finding is that when the inner and outer edges did not share the same contrast polarity, subjects often set the luminance of the test disk to match the polarity of the outer edge, particularly when outer edge contrast was relatively high. All the data were quantitatively modeled with a theory in which weighted edge signals are spatially summed to determine surface brightness. The modeling results generally support the idea that the inner edge partially blocks the influence of signals from the outer edge. Departures from blocking (enhancement of the induction signal) coincide with instances in which subjects matched the polarity of the test disk to the outer reference edge. We also show that the value of the blocking parameter must vary with either the contrast of the outer edge or the luminance of the background.

◆ **Increasing and decreasing the Chevreul illusion by a background luminance ramp**

J Geier, L Sára¶, L Bernáth§, M Hudák§ (Stereo Vision Ltd, Nádasy Kálmán u.34, H 1048 Budapest, Hungary; ¶Institute of Pedagogy, Kodolanyi Janos University College, Szabadságarcos u. 59, H 8000 Székesfehérvár, Hungary; §Institute of Psychology, Eötvös Lóránd University, Izabella u. 46, H 1064 Budapest, Hungary; e-mail: janos@geier.hu)

Chevreul illusion is a luminance staircase comprising homogeneous grey steps whose border neighbouring a lighter step appears to be darker. The generally accepted explanations for this illusion are based on the concept of centre–surround antagonism. We think that the predictions of these explanations contradict actual perception, as our psychophysical experiment ($N = 20$) shows. To test this concept, we inserted the luminance staircase in a luminance ramp as background. Afterwards, we girdled the previous image with another background ramp. The variations of these images were presented on a computer screen. Subjects could modify the gradient of the outer ramp, until they perceived that each step of the inner staircase became homogeneous. When the direction of the luminance change of the background ramp and the inner staircase was different, the illusion decreased or ceased, whereas it increased in the opposite case. Another ramp encompassing the image including the staircase and its first background ramp had no impact on the perception of the inner luminance staircase. Consequently, edges behave as segment boundaries, and the impact of the background ramp infiltrates only through one segment boundary. To explain these results, we present a computational model, and its computer simulation. [Supported by Stereo Vision Ltd, Hungary.]

MOTION PERCEPTION, BIOLOGICAL MOTION

◆ **Stable interindividual differences in the perception of ambiguous two-frame motion**

C Becker, J D Mollon (Department of Experimental Psychology, University of Cambridge, Downing Street, Cambridge CB2 3EB, UK; e-mail: cb486@cam.ac.uk)

The successive presentation of two sinusoidal gratings spatially shifted relative to each other provides an ambiguous motion stimulus. When observers are asked to determine its motion direction some show performance consistent with the physical stimulus, while others are not able to discern motion direction, or even report backward motion (Morgan and Cleary, 1992 *Vision Research* 22 2195–2198). The aim of this study was to quantify interindividual variability in the perception of ambiguous motion in a two-frame sequence. Testing twenty-three participants with gratings of different spatial frequencies (0.89, 1.78, 3.56 cycles deg⁻¹) and varying spatial shifts (10°, 50°, 90°, 130°, 170°) we found substantial variation between observers. The data were transformed

Thursday

with the Brown–Forsythe transformation and subjected to an ANOVA to assess the dependence of interindividual variability on the experimental factors. While variability was comparable for different spatial frequencies, it was highest for spatial shifts of 50°, 90°, or 130°. In these conditions, participants can be placed on a continuum between almost errorless performance and detection at chance level. No observer consistently reported backward motion. When extended training with feedback was given to twelve of the previous participants, only one observer showed improved performance, a result suggesting that the interindividual differences may be constitutional.

◆ **Event perception and length evaluation of lines**

A Bastianelli, R A Grosso, G Vidotto¶ (Department of Psychology, University of Milano-Bicocca, 1 piazza dell'Ateneo Nuovo, I 20126 Milan, Italy; ¶ Department of General Psychology, Padua University, 8 via Venezia, I 35131 Padua, Italy; e-mail: alessia.bastianelli@unipd.it)

Event perception involves a number of judgments of qualities that are continuously changing. The question arises whether we are better in these kinds of judgments, so often used in real life. Eighty subjects were asked to compare the length of two lines presented in succession (ISI 2100 ms) to the left and to the right hemispace. To determine the point of subjective equality (PSE) the method of constant stimuli was used: the observer was shown a standard (S) stimulus (PSE at 84 mm) paired with one out of seven variable (V) stimuli. V lines were static, with a length ranging from 78 to 90 mm. S lines could be static or evolving (ie lengthening or shortening), produced by the motion of the two endpoints (bilateral evolution) or by the motion of only one endpoint (monolateral evolution, both left-to-right and right-to-left), with three different velocities. An underestimation of lines presented on the right was found only for static-lines (PSE = 82.2 mm, $F_{1,76} = 19.75$, $p < 0.001$), in accordance with literature. For evolving lines an effect of velocity was found ($p < 0.001$), with an underestimation of bilateral lines and shortening lines at greater velocity (ie 12 cm s⁻¹, PSE = 82.57 mm and PSE = 82.53 mm, respectively, $p < 0.001$). Results are discussed in light of an ecological explanation.

◆ **The effect of priming on motion distortion**

B Saeidian, A Najafian (Neuroscience Research Group, School of Medicine, Isfahan University of Medical Sciences, Hezar Jarib Street, Isfahan, Iran; e-mail: saeidian@med.mui.ac.ir)

The position of a briefly flashed stationary object is misperceived in the direction of a nearby motion; this is known as motion distortion (MD). Using priming of the moving object before motion initiation we investigated the influence of the information on the position of the moving object on the MD. In the first experiment, two circles appeared on the screen and started to move immediately in opposite directions. In the second experiment the stimuli were stationary for 220, 440, or 660 ms and then started to move as in the previous experiment. In both experiments the flashed stimuli were presented at the time of motion initiation. Subjects were asked to localise the position of two flashed objects, presented beside the moving object. We compared subjects' localisation error (MD) between these conditions. Estimated MD was 11.14, 10.68, 9.87, and 8.64 min of arc for priming durations of 0, 220, 440, and 660 ms, respectively. MD decreased significantly with priming time increase ($p < 0.05$). We conclude that priming before motion initiation decreases the position distortion of a stationary object due to motion signals. Then MD may be in part due to an inaccurate perception of the moving object position and not only due to the motion signals.

[Supported by Talented Student Office, Medical Education Development Center, Isfahan University of Medical Science.]

◆ **Storage of local and global motion aftereffects: Adaptation mechanisms differ across cortical areas**

A J Shepherd (School of Psychology, Birkbeck College, University of London, Malet Street, London WC1E 7HX, UK; e-mail: a.shepherd@bbk.ac.uk)

After viewing moving displays, stationary or random motion displays can appear to move in the opposite direction [local and global motion aftereffects (MAEs), respectively]. It has been reported that local MAEs are only slightly reduced if there is a delay between the adapting and test displays ('storage'), whereas global MAEs do not store as well and depend on what is viewed during the delay. One conclusion is that local and global MAEs reveal adaptation at different cortical sites (early vs later) and that underlying cellular and network adaptation mechanisms differ at each site. This conclusion was addressed with adaptation to moving random-dot displays. Fifty participants subsequently viewed either stationary or dynamic (random motion) test displays. Two adaptation speeds were employed, optimised for local and global MAEs, respectively. Half of the trials included a 15 s delay between the adapting and test displays, during which participants either viewed a grey screen or closed their eyes. Global MAEs survived the delay

almost completely, whereas local MAEs were reduced. Global MAEs also stored better following eye closure during the delay. These results suggest that adaptation results in cellular suppression principally at early visual cortical areas. Sustained network changes following adaptation are implicated across cortical areas.

[Supported by Action Medical Research, Search, Migraine Action Association, University of London Central Research Fund, Faculty of Science, Birkbeck College.]

◆ **Position biases with moving stimuli**

Z Shi, M Goldbach, C de'Sperati¶ (Department of Psychology, Ludwig-Maximilians-Universität, Leopoldstrasse 13, D 80802 Munich, Germany; ¶ Visuomotor Functions Laboratory, Università Vita-Salute San Raffaele, via Olgettina 58, I 20132 Milan, Italy; e-mail: strongway@psy.uni-muenchen.de)

Motion generates illusions such as the flash-lag and the Fröhlich effects. Motion also shifts in its direction the perceived position of stationary stimuli flashed nearby. We mapped position distortions both of moving and of stationary stimuli within the region of space near the moving stimulus. A circular arc revolved at 0.5 cycle s^{-1} (4 deg eccentricity), and a spot was flashed at 6 different positions along the motion path, with 3 different eccentricities. At the end of each trial subjects positioned the circular arc at its perceived position at the time of the flash, and then moved the mouse cursor to the perceived flash position. We found: (i) a shift of the perceived flash position in the direction of motion ('push effect', range 9 to 39 min of arc); (ii) a bias in the perceived flash eccentricity, ranging from outward (13 min of arc) to inward (−9 min of arc), depending on the objective flash position; (iii) a shift of the perceived position of the arc in the direction of motion ('drag effect', 51 to 104 min of arc), much larger than the flash shift. These results can explain mislocalisation illusions in terms of a systematic distortion of positional information in the presence of motion stimuli.

◆ **Generality of anticipated velocity slowdown phenomenon in position-anticipation tasks of a free-falling object**

M Takeichi, K Fujita¶, H Tanaka§ (Faculty of Political Science and Economics, Kokushikan University, 1-1-1 Hirohakama Machida-city, Tokyo 195-8550, Japan; ¶ Department of Computer Sciences [§ Division of Biotechnology and Life Science], Tokyo University of Agriculture and Technology, 2-24-16, Naka-cho, Koganei-city, Tokyo 184-8588, Japan; e-mail: takeichi@kokushikan.ac.jp)

An experiment on position anticipation after occlusion of a free-falling object was carried out: A ping-pong ball was launched, freely fell down, and was occluded by a board in a virtual space. Subjects were required to report the ball position at the colour change of the board as a visual trigger stimulus, or at the short sound as an auditory trigger stimulus; these trigger stimuli were given after the occlusion at five levels of delays. We found that all the subjects underestimated the occluded object's moving distance after the occlusion in both tasks. The moving distance underestimates were observed at different object velocities (1 m s^{-1} , 3 m s^{-1}). The moving distance underestimates suggest that anticipated object velocities were less than actual velocity even in the slower moving condition. Therefore, the anticipated velocity slowdown appears to be a robust phenomenon. One of the possible features of the task is tracking the position of a moving object visually and reporting the anticipated position with a spatially fixed scale. This might affect eye movement, perceived object velocity, and the anticipated velocity. Measurement of the eye movement during the task will be performed so as to reveal the cause of the observed anticipated velocity slowdown.

◆ **Different types of motion changes evoke similar N2 component in VEPs**

A Uusberg, J Allik¶, J Kremláček§, N Kuldkepp (Department of Psychology [also Estonian Centre of Health and Behavioural Sciences], University of Tartu, Tiigi 78, EE 50410 Tartu, Estonia; § Department of Pathological Physiology, Faculty of Medicine in Hradec Králové, Charles University in Prague, CZ 50038 Hradec Králové, Czech Republic; e-mail: ro@ut.ee)

According to the kinematic energy model, the visual system essentially reduces detection of motion changes to detection of motion onset via subtractive normalisation. The model has been empirically validated in several experiments where reaction times and perceptual thresholds related to motion change detection depended only on absolute difference between motion vectors and initial velocity. Current experiments were designed to explore if there is also a common component in visual evoked potentials (VEPs) for different types of motion changes. VEPs were measured in response to motion onsets, offsets, reversals, and abrupt speed increases and decreases. The results showed that the N2 component that is related to motion processing in several previous works on motion onsets is also the most prevalent component for speed increases and can be

Thursday

identified in responses to speed decreases and motion reversals and offsets as well. The dependence of N2 parameters on absolute velocity difference is shown to be similar to results based on reaction times and detection thresholds.

◆ **Spatiotemporal properties of apparent-motion detection**

R J E Bours, M Kroes, M J M Lankheet (Functional Neurobiology, Helmholtz Institute, Utrecht University, Padualaan 8, NL 3584 CH Utrecht, The Netherlands; e-mail: R.J.E.Bours@bio.uu.nl)

We constructed a new random-dot motion stimulus to measure spatial and temporal tuning of motion-coherence detection. The stimuli comprise a single combination of spatial displacement and temporal interval, and lack correlations over multiple motion steps. Moreover, spatial displacement and temporal interval can be manipulated without varying the temporal-frequency content. We measured coherence thresholds for left–right motion direction discrimination in a staircase procedure by varying the percentage of dots moving coherently. The aim of the present set of experiments was to compare tuning for regular and for reversed apparent-motion detection. Our finding is that both spatial and temporal tuning are highly comparable for the two types of motion. This finding suggests that reversed apparent-motion detection does not result from spurious motion energy introduced by contrast reversals, but from specific sensitivity to the contrast reversal.

◆ **Detection of motion onset dependent on background motion**

N Kuldkapp, J Allik¶, K Kreegipuu§ (Department of Psychology [¶ also § Estonian Centre of Health and Behavioural Sciences], University of Tartu, Tiigi 78, EE 50410 Tartu, Estonia; e-mail: nele.kuldkapp@ut.ee)

The dependence of motion detection on the left–right direction and velocity ($0, 1.15, 6.9 \text{ deg s}^{-1}$) of the background motion was investigated by two methods: simple reaction time to the onset of the target motion (rightwards $1.15, 2.3, 3.45, \text{ or } 6.9 \text{ deg s}^{-1}$) and subjective judgments of the velocity of the target motion. As the results from seven observers point out, background movement, especially in the same direction as the target, did both: prolonged the motion detection, and let the velocity of the target appear slower in subjective ratings. The negative effect of the background motion on the perception of the target motion increased with the greater similarity between the target and background velocity. Comparing the two used methods, we found similar trends in relation to background motion in the case of relatively fast-moving targets (6.9 deg s^{-1}) and a discrepancy for the slower-moving targets (1.15 deg s^{-1}).

[Supported by ETF 6244.]

◆ **Contrast and pattern cues in the perception of motion transparency**

A I Meso¶, J M Zanker (Department of Psychology [also ¶ Vision Research Group], Royal Holloway University of London, Egham TW20 0EX, UK; e-mail: a.i.meso@rhul.ac.uk)

When surfaces are superimposed additively, transparency is perceived if sufficient visual cues are available to separate the components. These cues include, but are not limited to, spatial layout, relative contrast, and motion (speed and direction). For motion transparency of square-wave gratings, we explored the role of contrast and spatial-frequency information and their relationship to motion parameters. We used a number of 2AFC tasks in which, for example, the stimulus is a pair of gratings moving in the same direction at variable speeds. Participants were presented with these stimuli for 0.78 s and asked to identify the faster grating from images of the individual components displayed after each trial. In an initial configuration, when gratings of different spatial frequency were used as stimuli, separation was largely independent of relative contrast above a threshold velocity difference. For gratings with the same spatial frequency, relative contrast became crucial for separation, gaining importance as speed differences were reduced. These results are compared with motion signal histograms resulting from a correlation-type computational model of global motion. We discuss the combined influence of stimulus parameters on the percept of transparency in the context of the separation of signals in such histograms.

[Supported by CASE: EPSRC and Holviz Ltd.]

◆ **Onset repulsion and onset flash-lag: Effects on a stationary stimulus**

T L Hubbard, J R Courtney (Department of Psychology, Texas Christian University, TCU Box 298920, Fort Worth, TX 76129, USA; e-mail: t.hubbard@tcu.edu)

Memory for the location of a briefly presented stationary object aligned with the initial position of a target that exhibited implied motion was examined. The stationary object and moving target were presented on an otherwise blank background. Memory for the location of the stationary object was displaced backward (ie in the direction opposite to target motion), and memory for

the initial location of the moving target was also displaced backward (consistent with an onset repulsion effect; Thornton, 2002 *Spatial Vision* **15** 219–243). The magnitude of backward displacement was larger for the stationary object than for the moving target. Displacement in memory for the initial location of the moving target was not influenced by whether a stationary object aligned with that initial location was also presented. Observers judged the stationary object as lagging behind the initial position of the moving target (consistent with an onset flash-lag effect; Eagleman and Sejnowski, 2000 *Science* **287** 2036–2038). Implications for theories of the onset repulsion effect and theories of the flash-lag effect, as well as displacement in memory for location more generally, are discussed.

◆ **The motion aftereffect under scotopic conditions**

A Martin, A M C Werner (Department of Ophthalmology, University Eye Hospital Tübingen, Röntgenweg 13, D 72076 Tübingen, Germany; e-mail: annet.martin@web.de)

Motion aftereffect (MAE) refers to the illusory movement of a physically stationary scene following exposure to visual motion. It has been extensively studied for photopic light conditions. Here we investigate the MAE for rod-related vision. Adaptation stimulus was a drifting (2 Hz) horizontal sine-wave grating (2 cycles deg^{-1} , luminance defined) which was presented on a CRT screen (adaptation time 30 s). In the test, the same pattern was presented in a stationary mode. The duration of the MAE was measured and compared for scotopic (0.04 cd m^{-2}) and photopic (42.5 cd m^{-2}) light levels, which were varied by means of neutral-density filters. Twenty-five subjects participated in the experiments. Their task was to indicate the duration of the perceived MAE by pressing a button. Ten trials per subject were carried out under each light condition. In both, photopic and scotopic, conditions subjects experienced different degrees of MAE. For 25% of the subjects, a significant increase of the duration of the MAE was measured under the scotopic condition as compared to the photopic MAE. The implications for the cortical processing of rod signals are discussed.

[Supported by a grant (Kr 1317/8) by the DFG.]

◆ **The effect of motion adaptation on motion-induced blindness**

K Inoue, T Kikuchi (Institute of Comprehensive Human Sciences, University of Tsukuba, 1-1-1 Tennodai, Tsukuba, Ibaraki 305-8572, Japan; e-mail: inoue421@human.tsukuba.ac.jp)

Salient static stimuli disappear and reappear alternately for several seconds when they are surrounded by moving stimuli (motion-induced blindness, MIB). We examined the effect of motion adaptation on MIB. In motion adaptation condition, a moving stimulus (a 7×7 array of equally spaced blue crosses rotating around the centre of the array) preceded a static stimulus (a yellow small dot) by 20 s. In control condition, the array of blue crosses was presented for 20 s without rotating and then started to rotate at the onset of the static stimulus. Observers pressed mouse button when the static stimulus disappeared. The time between the onset of the static stimulus and button-press was measured (disappearance latency). The disappearance latency was longer in the motion adaptation condition than in the control condition. We suggest that motion adaptation reduces the interference of the moving stimulus with the processing of the static stimulus and therefore prolongs the disappearance latency.

◆ **Topographic map of the motion aftereffect**

A Ezzati, A Golzar, S R Afraz (School of Cognitive Sciences [SCS], Institute for Studies in Theoretical Physics and Mathematics [IPM], Niavaran, PO Box 19395-5746, Tehran, Iran; Research Center for Brain and Cognitive Sciences, Shaheed Beheshti University of Medical Sciences, Tehran, Iran; e-mail: ezzati_ali@yahoo.com)

Topographic organisation of the motion aftereffect was measured on small test stimuli after adaptation to motion. The stimuli were random dots embedded in a 9×9 grid. In each adaptation trial, the dots in the central 5×5 grid holes were coherently moving in one direction for 5 s. After adaptation, a small random-dot pattern filling one of the randomly selected grid holes was presented moving at various speeds for 0.2 ms. The subjects' task was to report perceived direction of the test stimulus by pressing one of two keys on the keyboard. The subjects' accuracy in direction discrimination was plotted as a function of test stimulus speed. Psychometric function shift in adapted trials compared to the non-adapted control condition was measured with fitted logistic curves. The shift value was defined as the strength of the motion aftereffect (MAE). To provide a fine topographic map of MAE we measured its strength for all grid holes. We found that this strength is highest in the internal edge of the adaptation area, parallel to the motion direction ($p < 0.03$). We also found a small positive aftereffect in background areas adjacent to the adaptation area. This background effect was asymmetrically stronger in areas in the direction of motion.

Thursday

◆ **MEG response to biological motion in the right temporal cortex is modulated by periventricular lesions**

M Pavlova, C Bidet-Ildei¶, A Sokolov§, C Braun#, I Krägeloh-Mann (Developmental Cognitive and Social Neuroscience Unit, Department of Paediatric Neurology and Child Development, Children's Hospital, University of Tübingen, Hoppe-Seyler-Strasse 1, D 72076 Tübingen, Germany; ¶ Laboratory of Psychology and Neurocognition, CNRS UMR 5105, Université Pierre Mendès-France, F 38040 Grenoble Cedex 9, France; § ZNL Center for Neuroscience and Learning and Department of Psychiatry III, University of Ulm Medical School, Leimgrubenweg 12, D 89075 Ulm, Germany; # Institute of Medical Psychology and Behavioural Neurobiology, MEG-Center, University of Tübingen, Ottfried-Müller-Strasse 47, D 72076 Tübingen, Germany; e-mail: marina.pavlova@uni-tuebingen.de)

Veridical processing of biological motion is of immense value in a variety of daily-life activities (safe self-locomotion and car driving) and for adaptive social communication. Although neurobiological mechanisms underlying the perception of biological motion are being explored extensively by brain imaging, the role of subcortico-cortical brain connectivity is not well understood. Here we ask whether and, if so, how cortical activity in response to point-light biological motion is modulated by early damage to periventricular regions that affects the pathways interconnecting subcortical structures with cortex. To this end, we assessed changes in the MEG response to biological motion in adolescents who were born premature with periventricular leukomalacia. The visual sensitivity to biological motion was lower in patients than in controls. In accord with behavioural data, RMS (root-mean-square) activation at latencies 180–240 ms over the right temporal cortex was weaker in patients. In this time window, the sensitivity to biological motion in controls (but not in patients) is negatively correlated with the right temporal activation. The findings suggest that periventricular lesions affect the interrelations between subcortical structures and the right temporal cortex, leading to disintegration of neural network engaged in biological motion processing, and provide insights into the neuroanatomy of biological motion. [Supported by DFG.]

◆ **On the role of speed and direction in localising motion defined contours**

S Durant, J M Zanker (Department of Psychology, Royal Holloway University of London, Egham TW20 0EX, UK; e-mail: szonya.durant@rhul.ac.uk)

Detecting discontinuities in motion signal distributions is an important aspect of visual perception and visuomotor control. It is not known whether speed and direction in the brain are encoded as a combination, ie velocity, or whether these attributes, in fact, are processed separately. We used a simple paradigm that examined how localisation accuracy for a motion-defined contour depends on the velocity differences that define the contour. Within a square, $7.5 \text{ deg} \times 7.5 \text{ deg}$ in area, two fields of randomly positioned black dots were moving on a grey background. The motion of the dots differed across the two fields in either speed, direction, or both. The location of the discontinuity between the two fields was varied horizontally around the centre. Subjects were asked in a 2AFC single interval task whether the boundary between the two fields was to the left or to the right of the fixation target. Just noticeable differences were determined from fitted psychometric curves and compared for different speed and direction conditions. We find that the ability to localise the contour is not simply dependent on the velocity difference, and discuss this in the context of direction and speed-specific areas of the visual cortex. [Supported by EPSRC.]

◆ **Attentional modulation of psychophysical tuning curves for direction of motion**

C Tillmann, L Busse, S Katzner, S Treue (Cognitive Neuroscience Laboratory, German Primate Center, Kellnerweg 4, D 37077 Göttingen, Germany; e-mail: tillmann.christine@gmail.com)

Competing mechanisms have been proposed to account for the effects of attention on visual information processing, namely enhancement of the processing gain vs changes in the selectivity, ie the width of perceptual filters. Here, we used a psychophysical variant of the motion reverse correlation (MRC) method in a dual-task paradigm to investigate the effect of attention on the selectivity for motion direction. The stimulus consisted of an eccentrically presented random sequence of fully coherent, rapid motion impulses in various directions. Subjects were required to press a key each time they detected a designated target direction. Every subject performed the motion detection task under two conditions, differing in attentional load (high vs low) of the concurrent second task. By reverse correlating behavioural responses with individual motion impulses, we obtained Gaussian-shaped direction-tuning curves for each attentional condition.

Comparing amplitude and width of the tuning curves across the two attention conditions revealed that attention leads to an increase in amplitude of about 10%, and a decrease in width of about 6%. These results demonstrate that attention can narrow the width of the perceptual filter, which might indicate an increase in the selectivity of the neuronal population response to motion direction.

◆ **Neural correlates of subjective rotation reversals in ambiguous structure-from-motion**

E D Freeman, P Sterzer ¶ (Institute of Cognitive Neuroscience, University College London, 17 Queen Square, London WC1N 3AR, UK; ¶ Department of Neurology, Johann Wolfgang Goethe University, Theodor-Stern-Kai 7, D 60590 Frankfurt am Main, Germany; e-mail: elliott.freeman@ucl.ac.uk)

Recent brain-imaging studies of bistable phenomena (eg binocular rivalry and bistable apparent motion) have shown neural correlates of subjective switches in extrastriate visual cortical areas. Little is known about the exact role of such switch-related activations in the dynamic resolution of perceptual conflicts. Here, we used functional magnetic resonance imaging to investigate the fine-tuning of switch-related responses to the visual features that are perceived to change in bistable motion stimuli. We examined the phenomenon of ambiguous structure-from-motion, using transparent random-dot kinematograms to produce the compelling impression of either a cylinder rotating in depth or two flat surfaces drifting in opposite direction at different depths. Such stimuli typically undergo striking spontaneous re-ordering of apparent surface depth and, uniquely for cylinders, reversals in the apparent direction of rotation in depth. Event-related activity associated with subjective switches was found for both stimulus types contralateral to the hemifield of presentation in early retinotopic visual areas V1, V2, and V3. hMT/V5+ activations were also observed in association with perceptual switches for both cylinder and flat-surface stimuli. In contrast, only cylinder stimuli produced lateralised switch-related activity in the lateral occipital complex (LOC) region of interest. This result implicates LOC as a neural correlate of subjective rotational reversals.

[Supported by BBSRC research grant S20366 and the German Research Society.]

Friday

FRIDAY

ORAL PRESENTATIONS

VISION AND GRAVITY

◆ **Adaptational modifications of the vestibular postural response in humans under conditions of horizontal visual reversal**

B Smetanin, K E Popov, G V Kozhina (Institute for Problems of Information Transmission, Russian Academy of Sciences, Bolshoi Karetnyi 19, 127994 Moscow, Russia; e-mail: finegold@yandex.ru)

We recorded stabilograms and studied postural responses evoked by galvanic stimulation of the labyrinth (binaurally applied 1 mA current, 4 s) with the subjects eyes open and closed and under conditions of horizontally reversed visual perception. In series consisting of 10 sequential tests with eyes open, we observed a gradual drop in the response amplitude, while there were practically no changes in the maximum velocity of the displacement. With eyes closed, both the amplitude and maximum velocity of the postural responses decreased with successive testing. At the beginning of a test series, responses to vestibular stimulation were greater with eyes closed, but in repeated tests they attained the same magnitude. Postural responses to galvanic stimulation of the labyrinth (monaurally applied, 2 mA current, 4 s) were tested with 1 h long intervals. A 3 h long interval with the prismatic spectacles on did not modify the amplitude and velocity of the vestibular postural responses when the tests were made with the eyes closed. With the eyes open, but with inverting spectacles, postural responses significantly decreased (by about 50%–60%) to the 2nd and 3rd hour of the experiment. This can be interpreted as a result of adaptational transformation of the visual-vestibular relation.

[Supported by the Russian Foundation for Basic Research (grant No. 05-04-49877).]

◆ **Stroboscopic vision as a treatment for motion sickness**

M F Reschke, J T Somers, G Ford, J M Krnavek, E Y Hwang, L N Kornilova[¶], R J Leigh[§] (Wyle, NASA Johnson Space Center, Human Adaptation and Countermeasures Office, Neuroscience Laboratory (SK272), 2101 NASA Parkway, Houston, TX 77058, USA; [¶]State Research Center, Institute of Biomedical Problems, Khoroshevskoye shosse 76A, Moscow 123007, Russia; [§]Biomedical Engineering and Neurosciences, Department of Neurology, Case Western Reserve University, Cleveland, OH 44106-5040, USA; e-mail: millard.f.reschke@nasa.gov)

Results obtained from space flight indicate that most space crews will experience some symptoms of motion sickness causing significant impact on the operational objectives that must be accomplished to assure mission success. On the basis of the initial work of Melvill-Jones, we have evaluated stroboscopic vision as a method of preventing motion sickness. Nineteen subjects read text while making $\pm 20^\circ$ head movements in the horizontal plane at 0.2 Hz while wearing left–right reversing prisms during exposure to 4 Hz stroboscopic or normal room illumination. Testing was repeated with LCD shutter glasses as the stroboscopic source with an additional nineteen subjects. With strobe, motion sickness was significantly lower than with normal room illumination. Results with the LCD shutter glasses were analogous to those observed with environmental strobe. Stroboscopic illumination appears to be effective where retinal slip is a factor in eliciting motion sickness. Additional research is being carried out evaluating the efficacy of the glasses for car sickness, sickness in parabolic flight, and sea sickness. There is evidence from pilot studies showing that the glasses reduce saccade velocity to visually presented targets by approximately half of the normal values. It is interesting to note that adaptation to space flight may also slow saccade velocity.

[Supported by NSBRI Grant NA00208, Johnson Space Center Director Discretionary Funds, NASA Space Act Agreement and NIH Grant EY06717.]

◆ **Influence of attention and visual stimulation conditions on the programming of saccadic eye movements in man**

V V Shulgovsky, M V Slavutskaya, V V Moiseeva (M V Lomonosov State University, Mokhovaya 8/5, 103009 Moscow, Russia; e-mail: shulg@mail.ru)

The visual system is inseparably linked with the saccadic one. These systems form the sensory and motor components of visual behaviour. Fifty-four healthy volunteers took part in the experiments. We showed the influence of attention processes and visual stimulation conditions on the intensity and topography of presaccadic EEG potentials. Monocular and binocular stimulations to the dominant and subdominant eyes were used. Selected EEG averaging was used before short-latency saccades, express saccades, and long-latency saccades. Mapping of the EEG amplitudes

of the visually guided and presaccadic potentials showed that the brain substrate of attention processes consisted of an interaction between frontal-parietal oculomotor areas of the right and left hemispheres. The right hemisphere dominates in the perceptual and spatial attention and the left one in the motor attention processes. Switching-on of attention at the stages of movement presetting, of visual perception, and of saccadic initiation is reflected in the activation of the frontal-, central-, and parietal-occipital areas. Also, this switching-on is reflected in the activation of the frontal-medio-thalamic and thalamo-parietal modulatory systems of the selective attention and motivation. Brain asymmetry of the saccadic generation processes and the dominant role of the dominant eye in the attention, visual perception, and anticipation were found.

[Supported by the Russian Foundation for Basic Research (project 96-05-4-48259) and the Russian Humanitarian Foundation for Basic Research (project 04-06-00261a).]

- ◆ **The collinearity of Listing's plane and the vestibulo-oculomotor response in microgravity**
A H Clarke, T Haslwanter (Vestibular Research Laboratory, Campus Benjamin Franklin Charit Medical School, Hindenburgdamm 30, D 12200 Berlin;
e-mail: andrew.clarke@charite.de)

The internal coordinates of the vestibular system are defined by the orientation of the 3-D vestibulo-ocular reflex (3-D VOR), and those of the oculomotor system by the so-called Listing's plane. The internal, neurally represented coordinate systems related to the vestibular and oculomotor systems are generally thought to be collinear under normal gravity conditions. The working hypothesis is that in microgravity the orientation of the Listing's plane diverges from that of the VOR coordinate frame. The orientation of the 3-D VOR is determined by measurement and analysis of eye and head movements during active head roll, pitch, and yaw movements. Listing's plane is calculated from measurements of random saccades. All eye and head movements are recorded and measured with the DLR eye-tracking device, a flight version of which is installed on the International Space Station (ISS). To date, the results indicate that not only the orientation of the 3-D VOR, but also that of the Listing's plane of the individuals is altered during microgravity. This demonstrates that the otolith-mediated gravity vector represents a common spatial reference for the central nervous system, the loss of which may lead to a dissociation of these closely coupled systems.

[Supported by Deutsches Zentrum für Luft und Raumfahrt grant WB 0023.]

- ◆ **Experimental study of static ocular counterrolling under altered gravity environment**
A G Yakushev, I V Boukhtiarov¶, G R Kaspranskaya§, R R Kaspransky# (Applied Mechanics and Control Department, Mechanics and Mathematics Faculty, Moscow State University, Leninskie Gory, 119899 Moscow, Russia; ¶ State Scientific Research and Testing Institute of Military Medicine, Ministry of Defense of the Russian Federation, Moscow, Russia; § Sechenov Moscow Medical Academy, Bolshaya Pirogovskaya 2/6, 119881 Moscow, Russia; # Gagarin Cosmonaut Training Center, Star City, 141160 Moscow Region, Russia;
e-mail: moids@yandex.ru)

Our object was to clarify the dependence of static ocular countertorsion on the lateral and longitudinal components of the gravito-inertial vector. Rotations in a human 18-m centrifuge were performed to produce different static lateral overload levels against the background of enlarged or reduced longitudinal overload. In particular, negative and zero longitudinal overloads were reproduced. Static body tilts were also performed in frontal plane up to 180°. Eye movements were recorded in darkness by videooculography. For the sake of comparison, at some rotations, the subjects were instructed to fix a 0.5 cm target located 70 cm from the subject's head. In static tilts, it was found that compensatory torsion is proportional to head (body) tilt up to approximately 30°–45°. Further increase of body tilt up to 135°–150° produces nearly constant ocular response. All subjects demonstrated response asymmetry up to 24°. In accelerated rotations, horizontal, vertical, and torsional nystagmus was found in all the subjects. Target fixation significantly suppressed the nystagmus. Calculations demonstrate that static ocular counterrolling is a complex response to lateral overload, as well as to the magnitude and direction of the longitudinal component of the gravito-inertial vector, and to the magnitude of overload.

- ◆ **The role of gravity-dependent systems in visual pursuit**
M Alekhina¶, L N Kornilova, V V Temnikova, I A Naumov, K A Azarov, I Kozlovskaya§ ([¶ Department of Vestibular Research; § Department of Sensory-motor Physiology and Countermeasure], RF State Research Center–Institute for Biomedical Problems of the Russian Academy of Sciences, Khoroshevskoe shosse 76A, 123007 Moscow, Russia;
e-mail: L.Kornilova@wizards.pp.ru)

The role and significance of vestibular and tactile-support systems in the formation of the eye pursuit function is of interest. Studies were performed on eleven cosmonauts after 126 to 195

Friday

days of microgravity. 7-day dry immersion was performed, involving eighteen subjects, nine of whom received additional support afferentation. Visual responses (static and dynamic saccades, smooth pursuit) were recorded in subjects by electrooculography (EOG), and in cosmonauts by two methods simultaneously: videooculography and EOG. We found that during microgravity there is a decrease of accuracy of all forms of visual pursuit. Our studies reveal a significant change in velocity and time characteristics of visual pursuit. These disturbances are induced by sensory deprivation developing during microgravity. Immersion, while removing support and minimising muscle activity, has no direct effect on the vestibular receptor. Here, no significant changes under the experimental conditions used by us could be found. The use of additional support afferentation was found to make the visual pursuit function more stable. A comparative analysis of the post-flight and experimental data obtained demonstrated a leading role of the vestibular system in the realisation of visual pursuit.

- ◆ **Effect of 6-days dry immersion on cortical slow potentials preceding voluntary saccades**
E Tomilovskaya, A V Kirenskaya¶, V Y Novototski-Vlasov¶, I Kozlovskaya (Department of Sensorimotor Physiology and Countermeasure, RF State Research Center—Institute for Biomedical Problems of the Russian Academy of Sciences, Khoroshevskoe shosse 76A, 123007 Moscow, Russia; ¶ Serbsky National Research Center for Social and Forensic Psychiatry of the RF Ministry of Health, Kropotkinskiy h.23, 119992 Moscow, Russia; e-mail: finegold@yandex.ru)

The study was performed before and after 6-day dry immersion. Data of seven right-handed volunteers were analysed. Three LEDs were used for stimulation: the central LED served as a central fixation point, LEDs located 10 deg right and left of the fixation point were the peripheral targets. The subjects performed saccades to the horizontal mirror position of the peripheral targets. EEG was recorded from 19 leads. A mean of presaccadic negativity amplitude was evaluated over two intervals before peripheral target onset: (i) 600–400 ms, (ii) the last 200 ms. Two stages of presaccadic negativity were revealed before dry immersion. CNV-like early negative wave (1st interval) localised over frontal-central-parietal area with a maximum at Fz (frontal middle site). Late negative wave (2nd interval) included frontal and parietal foci with maxima at the midline and left sites. After dry immersion, the early-stage maximum of presaccadic negativity was localised at Cz (vertex). Later, negativity foci shifted to central and parietal-occipital sites of the right hemisphere. We suggest that left hemisphere and prefrontal cortex functions, initially dominating in organisation of motor responses, undergo deactivation due to support unloading and decline of proprioceptive activities in microgravity, which should lead to the decline of prefrontal cortex activation and transition of dominance in motor control to the right hemisphere.

[Supported by RFBR grant number 06-04-49660-a and by BIAL grant N 58/04.]

- ◆ **The gaze fixation reaction in monkeys during the initial stage of support deprivation**
A Badakva, N V Miller, J N Eron (Laboratory of Experimental Neurophysiology, Russian Federation State Research Center—Institute for Biomedical Problems of the Russian Academy of Sciences, Khoroshevskoe shosse 76A, 123007 Moscow, Russia; e-mail: finegold@yandex.ru)

Our previous studies on monkeys immersed to mid-chest level showed that this model reproduces microgravity effects on the gaze-fixation reaction. Our purpose here was to evaluate the influence of water immersion on the gaze-fixation reaction in rhesus monkeys during the initial stage of support deprivation. The gaze-fixation reaction was studied before and during thermo-neutral water immersion to mid-chest level (3 animals) or to neck level (2 animals). The animals were trained to perform the conditioned reflex motor task (eye–head–hand coordination) and were implanted with electrodes to record their electro-oculogram. The angular vestibulo-ocular reflex gain increased and the angular velocity of the head decreased significantly in 3 monkeys 5 h after the start of immersion to mid-chest level. Although gain and head velocity changes could have occurred independently, since they occurred in parallel, it is more likely that one of them was primary, while the other was an adaptive response to the primary change. Peak velocity of the head movements decreased significantly without significant increase of the angular vestibulo-ocular reflex gain in 2 h of the neck-level immersion. Thus, support deprivation affects the control of head movements first.

ART—PERCEPTION AND IMAGINATION

- ◆ **Kinetic art: reverspectives, intaglios, and termespheres—why do they ‘move’?**
T V Papathomas (Department of Biomedical Engineering and Laboratory of Vision Research, Rutgers University, 152 Frelinghuysen Road, Piscataway, NJ 08854-8020, USA; e-mail: papathom@rci.rutgers.edu)

The issue of how humans, under self-motion, determine whether surfaces and objects in the environment move or are stationary is still debated by proponents of inferential theories and

direct-perception theories. Certain classes of works of art highlight this issue because they appear to move vividly as viewers move in front of them, even though they are stationary. These classes include Patrick Hughes's 'reverspectives', Dick Termes's 'termespheres', intaglios, and hollow masks. I present a unified geometric explanation based on Gogel's theory of phenomenal geometry. The explanation considers this illusory motion as a result of the perceived depth reversal that accompanies the illusory motion, whereupon convex and concave surfaces are falsely seen as concave and convex, respectively. The main tenet is that the visual system constructs a three-dimensional representation of the surfaces, and that this representation is one of the sources that contribute to the illusory motion. This explanation is extended to the case of stereograms that also appear to move under self-motion, to derive formulas for the illusory depth and motion as a function of viewing distance, interocular distance, stereo parallax, and extent of self-motion.

◆ Visual perception and memory of indeterminate art compositions

A Ishai, S L Fairhall, R Pepperell (Institute of Neuroradiology, University of Zurich, Winterthurerstrasse 190, CH 8057 Zurich, Switzerland; e-mail: ishai@hifo.unizh.ch)

Visual indeterminacy occurs when subjects view apparently detailed and vivid images that resist object recognition. We hypothesise that, compared with determinate paintings, subjects would be slower to detect the presence of recognisable content and to report the aesthetic affect of indeterminate images. Twenty-six subjects (thirteen females, mean age 29 years) performed a recognition task followed by an aesthetic-affect task. Surprisingly, subjects perceived recognisable content in 24% of the indeterminate images. Regardless of image type (determinate vs indeterminate), subjects similarly rated the aesthetic affect of all paintings. Nevertheless, response latencies for the indeterminate images were significantly longer. One week later, fourteen subjects performed a surprise memory test, in which the previously seen paintings were mixed with novel ones. Subjects correctly remembered more determinate paintings (Hit = 59%, CR = 79%) than indeterminate paintings (Hit = 65%, CR = 62%). For all paintings, as affective strength increased, so did the probability of recall. Our results suggest that perceptual aspects of paintings are sufficient to create a sense of meaning and despite the lack of recognisable content to elicit affective responses. Regardless of image type, aesthetic judgment was equivalent and a valid predictor of memory performance. The longer latencies associated with indeterminate images likely reflect cognitive processes that mediate object resolution.

[Supported by the Swiss National Center for Competence in Research: Neural Plasticity and Repair.]

◆ Turner's translation of colour into black and white

A C Hurlbert (Institute of Neuroscience, Department of Psychology, University of Newcastle, Framlington Place, Newcastle upon Tyne NE2 4HH, UK; e-mail: anya.Hurlbert@ncl.ac.uk)

J M W Turner is known for the rich, evocative, and experimental use of colour in his late paintings. Many of his works were also reproduced as monochromatic engravings, and the challenges of translating the moods and meaning of his colour paintings into 'black and white' have been addressed by many writers, notably John Gage. But the reverse translation—from black and white into colour—is also key to understanding one aspect of Turner's evolution as a painter. This evolution is apparent in his treatment of favourite sites which he drew for his *Liber Studiorum* (LS), an early book of engravings, and painted again and again as he aged, adding colour and removing line—Norham Castle in Northumberland being a prime example. For Turner, at the time of the LS, the value of colours lay largely in their varying luminance—his deep concern with light and shade enabled him to "ignore local colour" (as A J Finberg wrote) and made engraving natural to him. In later works, as I argue here, Turner moved away from narrative and design, naturally depicted by monochromatic texture and line, towards more emotion and evocation, expressed in swathes and vortices of colour contrast.

◆ Looking backward: New perceptions of the original Sistine Chapel

P Trutty-Cooill (Creative Arts Department, Siena College, 515 Loudon Road, Loudonville, NY 12211-1462, USA; e-mail: ptrutty@siena.edu)

The controversies over the cleaning of the Sistine Chapel were almost completely based on perceptions: the colours were too bright, Michelangelo's famed ability at draughtsmanly modeling was lost, etc., etc. This paper addresses the lived experience of the cleaned Sistine Chapel. It examines the new experiences of the beholder, compares them with the old, and relates the experience to the meaning of the whole. Rather than destroy meaning, the cleaning reveals the worlds Michelangelo and his contemporaries sought to perceive.

Friday

◆ **Individual differences in interpretations of abstract visual representations: visual art vs kinematics graph**

O Blajenkova, M Kozhevnikov, M A Motes (Department of Psychology, Rutgers University, Smith Hall, 101 Warren Street, Newark, NJ 07102, USA; e-mail: olessia@pegasus.rutgers.edu)

We explored individual differences in processing and interpreting abstract visual representations. We took a new approach to examining individual differences in visual imagery that relied on a key distinction regarding visual processing, namely the distinction between object and spatial processing. Object visualisers prefer to construct colourful, pictorial, high-resolution images of objects, but spatial visualisers prefer to use imagery to schematically represent spatial relations among objects and to perform spatial transformations. We examined correlations between responses on object and spatial imagery measures and interpretations of abstract art and kinematics graphs. Furthermore, we monitored the eye movements of object and spatial visualisers (selected on the basis of their performance on object and spatial imagery measures) while they studied and interpreted abstract art and kinematics graphs. Finally, we found that visual artists tended to be object visualisers but scientists tended to be spatial visualisers. Overall, object and spatial visualisers tended to interpret abstract art and kinematics graphs qualitatively differently. Object visualisers tended to interpret the abstract art as abstract representations, but spatial visualisers tended to interpret abstract art literally, in a concrete way. However, object visualisers tended to interpret graphs literally (graphs-as-pictures), but spatial visualisers tended to interpret graphs schematically, in abstract way.

◆ **Relating nonlinearities to statistical regularities in paintings**

D J Graham, K B Page, D J Field (Department of Psychology, Uris Hall, Cornell University, Ithaca, NY 14853, USA; e-mail: djg45@cornell.edu)

We studied the ways painters compress the range of luminances present in the natural world into the far smaller range available for painted art. Earlier work suggests that a diverse group of scanned paintings is similar to natural scenes in terms of statistical and modeled neural-response properties. While this work suggests paintings recreate basic statistical properties of natural scenes whether subject matter is concrete or abstract, it also suggests artists apply luminance nonlinearities to paintings which resemble nonlinearities in early vision. We tested an expanded set of paintings to determine the extent to which low-level statistics and modeled responses can describe the provenance or type of paintings (landscape, portrait, or abstract). Image type experiments were based on forced-choice studies with human judges; judges agreed on classifications for 57 images. Sparseness of modeled retinal responses was similar for all types of paintings but, applying a static nonlinearity before filtering, landscapes were more sparse than the other types. Retinal response sparseness was higher for Western provenances but the same for Eastern and Western provenances with the nonlinearity. These regularities could help explain how artists approach the task of compressing the range of natural luminances at different spatial scales, in abstract form, and across cultures.

[DJG is supported by NIH EY015393 (Kirschstein-NRSA), DJF and KBP are supported by NGA contract HM 1582-05-C-0007 to DJF]

◆ **The eyes of Gogol—a Saint Petersburg Tale**

F Chessa, G J Brelstaff¶ (Università di Sassari, via Roma 151, I 07100 Sassari, Italy; ¶CRS4, Polaris, Ed.1, CP 25, I 09010 Pula, Italy; e-mail: fch@uniss.it)

Perception plays a significant role in Gogol's "St Petersburg Tales" written in 1830s. All five senses, and their organs, are invoked—and, most famously, 'The Nose' (Hoc) takes centre stage as it detaches itself from poor Kovalyov's face. We present a perceptuo-literary comparative analysis of these Tales, embarking, as did Gogol, from "The Nevsky Prospekt". Our current study focuses mainly upon the eye. We meet Petrovich, the one-eyed tailor of "The Overcoat", threading his needle, assisted by motion-parallax. We witness the visual processes of Tchartkoff's colleague in the "The Portrait" where "It was plainly visible how the artist, having imbibed it all from the external world, had first stored it in his mind, and then drawn it thence, as from a spiritual source, into one harmonious, triumphant song." Combining the spirit of both conference and venue, we aim to offer further insights to complement those of our fellow experimentalists and theorists.

◆ **Artful Bayes**

R Gregory (Department of Experimental Psychology, University of Bristol, 12A Priory Road, Bristol BS8 1TU, UK; e-mail: Richard.Gregory@bristol.ac.uk)

The Reverend Thomas Bayes (1702–1761) suggested a theorem for probability inference. Vision is seen as ambiguous retinal images modifying prior probabilities of objects in scenes, the most likely 'perceptual hypothesis' being generally accepted, and so seen. Objects represented in pictures are seen with probabilities derived from interacting with real objects, though no doubt

artists develop Bayesian priors for painter's styles, hence Schools of Art. Conversely, experiencing art may train eye and brain to see objects differently. Some illusions obey the Bayes theorem, such as the Hollow Face, but many are exactly opposed, including perspective–depth illusions, such as the Ponzo and Müller-Lyer distortions of expansion with represented distance. Some pictures are seen as impossible, such as the Penrose triangle, so having zero probability. This is a puzzle for Bayes—resolved by the brain generating perceptual hypotheses with general rules—which may create even zero probability including impossible perceptions. It seems that such violations of Bayes throw the strongest light on how perception works, and why art can be surprisingly effective.

SHADOW/ILLUMINATION

◆ Colour vision and illumination noise in primates and birds

T Troscianko, P G Lovell, C A Párraga¶, R Baddeley, D J Tolhurst§ (Department of Experimental Psychology, University of Bristol, 12A Priory Road, Bristol BS8 1TU, UK; ¶ School of Biological Sciences, University of Bristol, Woodland Road, Bristol BS8 1UG, UK; § Department of Physiology, University of Cambridge, Downing Street, Cambridge CB2 3EG, UK; e-mail: tom.troscianko@bris.ac.uk)

There is considerable evidence that the properties of primate colour vision are optimised to allow foraging for food. The data on which these conclusions are based are the reflectance spectra of fruit and leaves, and measures of the spectral composition of the illumination. However, the 3-D structure of natural scenes containing leaves results in considerable variation in the intensity and chromatic content of light reflected from different elements of each scene. We present data which show that the absorption spectra of cones in primates and passerine birds have an effect on the degree to which this illumination noise is encoded by the visual system. In particular, the close spacing of primate L and M cones results in a greater degree of invariance to shadows and illumination than the equivalent spacing of these cones in passerine birds. The results point to a trade-off between (a) achieving greater chromatic resolution, and (b) immunity from illumination noise. Given that primate vision has a particularly enhanced ability to ignore shadows and changes in the colour of the illumination, we present data to show that human observers are able to ignore such changes when making judgments about the degree of similarity of natural scenes. [Supported by EPSRC/Dstl Joint Grant Scheme grant number GR/S56405/01.]

◆ The role of local luminance amplitude in the interpretation of shape-from-shading in textured surfaces

A J Schofield, M A Georgeson¶, G Hesse, P B Rock, T A Yates¶ (School of Psychology, University of Birmingham, Edgbaston, Birmingham B15 2TT, UK; ¶ School of Life and Health Sciences, Aston University, Birmingham B4 7ET, UK; e-mail: a.j.schofield@bham.ac.uk)

Luminance changes within a scene are ambiguous; they can indicate reflectance changes, shadows, or shading due to surface undulations. How does vision distinguish between these possibilities? When a surface painted with an albedo texture is shaded, the change in local mean luminance (LM) is accompanied by a similar modulation of the local luminance amplitude (AM) of the texture. This relationship does not necessarily hold for reflectance changes or for shading of a relief texture. Here we concentrate on the role of AM in shape-from-shading. Observers were presented with a noise texture onto which sinusoidal LM and AM signals were superimposed, and were asked to indicate which of two marked locations was closer to them. Shape-from-shading was enhanced when LM and AM co-varied (in-phase), and was disrupted when they were out-of-phase. The perceptual differences between cue types (in-phase vs out-of-phase) were enhanced when the two cues were present at different orientations within a single image. Similar results were found with a haptic matching task. We conclude that vision can use AM to disambiguate luminance changes. LM and AM have a positive relationship for rendered, undulating, albedo textures, and we assess the degree to which this relationship holds in natural images. [Supported by EPSRC grants to AJS and MAG.]

◆ The apparent luminance contrast in impossible shadow displays

A Soranzo, A C G Galmonte¶, T A Agostini¶ (School of Social Science and Law, University of Teesside, Middlesbrough TS1 3BA, UK; ¶ Department of Psychology, University of Trieste, via San Anastasio 12, I 34134 Trieste, Italy; e-mail: a.soranzo@tees.ac.uk)

Shadows own the property that the luminance ratios along their edges are invariant. Shadows violating this property are defined as impossible shadows (ISs). Soranzo and Agostini (2004 *Perception* 33 1359–1368) found that ISs improve lightness constancy compared to possible shadows (PSs). They speculated that the luminance edges of ISs appear as illumination edges. In the present study, this hypothesis was further investigated by directly comparing the edges of

Friday

PSs and ISs. In a CRT experiment, the screen was vertically divided into two frames of illumination by a contextual edge. Two adjacent rectangles created the standard edge (ratio = 5 : 1) which was collinear with the contextual one. Two additional adjacent rectangles produced the target edge. Observers were asked to equate the target edge contrast to the standard edge contrast. Two variables were systematically manipulated: contextual edge luminance ratio; 1 : 1 (base line), 5 : 1 (PS), 10 : 1 (IS1), 15 : 1 (IS2); and the additional rectangle position; light, shadow. We found that the apparent contrast of the standard edge was lower in ISs than in PSs. This effect was stronger in the light condition of the additional rectangle position variable. Outcomes corroborate the hypothesis that luminance edges produced by ISs are perceived as illumination edges.

◆ **The shadow correspondence problem**

P Mamassian (CNRS and Université Paris 5, 71 Avenue Édouard Vaillant,

F 92774 Boulogne-Billancourt Cedex, France; e-mail: pascal.mamassian@univ-paris5.fr)

Cast shadows provide potentially rich information about the visual scene, in particular with respect to the location of objects in the scene. However, in order to use that information, our visual system has first to solve the shadow correspondence problem—that is successfully match shadow candidates with the appropriate objects. The similarities of this problem with the correspondence problems in binocular vision and in motion perception are outlined. On the basis of evidence from psychophysics and neuroscience, it is argued that the shadow correspondence problem is solved by a coarse-scale, low-level mechanism.

◆ **Cast shadows of our own body**

F Pavani (Department of Cognitive Sciences and Education, University of Trento, Corso Bettini 31, I 38068 Rovereto, Italy; e-mail: francesco.pavani@unitn.it)

Body shadows constitute a special kind of stimulus in our visual world. Similar to all cast shadows, they refer to a different portion of space than the one they occupy. In addition, unlike other cast shadows, they often bear anatomical resemblance to our body parts and they move as our body moves in spatiotemporal correlation. In a series of recent experiments, my colleagues and I have investigated how this peculiar visual stimulus may influence our body schema and orienting of attention to our own body parts. Body shadows can strongly affect perception of spatial relationships between our own body and the stimuli around us, bridging the gap between personal and extrapersonal space. In addition, body shadows can act as a powerful visual cue for orienting attention towards the body. Self-attributed body shadows cue attention to the body part they refer to, rather than the location they physically occupy. Our work suggests that body shadows may help to shed new light on issues like multisensory construction of the body schema and orienting of attentional resources to the body.

◆ **Constructing reality: Shadows, shading, and highlights in ancient, medieval, and renaissance art**

D Zavagno (Dipartimento di Psicologia, Università di Milano-Bicocca, piazza dell'Ateneo Nuovo 1, I 20126 Milan, Italy; e-mail: danielle.zavagno@unimib.it)

Light and space are embedded realities in our visual world. The correlation between these two visual entities is even more compelling in figurative arts. For example, the perception of illumination is highly correlated with the qualitative rendering of space by means of an appropriate display of depth cues. On the other hand, the depiction of 3-D objects owes much to light itself, in terms of its interactions with solid objects in the real world. In this work, I discuss the use of shadows, shading, and highlights made by artists to render 3-D structures in their masterpieces. I show the bag of tricks that enable artists to construct realities that in certain cases are at the same time locally coherent and globally disjointed. This peculiar combination often goes along with a pictorial space that protrudes from the plane, while perceptual depth is rather shallow and ambiguous. Some of the tricks have a logical explanation in evolutionary terms (for example those based on the assumption of light coming from above); others are still perceptual mysteries.

SACCADDES, EYE MOVEMENTS

◆ **Influence of retinal information on the smooth pursuit compensation signal**

C Morvan, M Wexler (LPPA/CNRS, Collège de France, 11 place Marcelin Berthelot, F 75005 Paris, France; e-mail: camille.morvan@college-de-france.fr)

The production of a smooth-pursuit eye movement modifies the retinal image, adding a velocity field to this image in the direction opposite to that of the eyes. Thus, to correctly perceive the physical motion of objects, the visual system has to compensate for this self-induced motion. This compensation is assumed to involve the combination of retinal and extra-retinal (an estimate of eye velocity) signals. How are these two signals combined? According to the linear model,

the estimated eye velocity is simply added to the retinal signal and the resulting motion is considered as the physical motion of the stimulus. We have studied this using stimuli moving in different directions and with different speeds. Our results contradict the linear model, and suggest that the compensation depends not only on the eye movement but also on retinal information such as the direction and speed of the stimulus.

[Supported by Fédération des Aveugles de France.]

◆ **Perceiving ocular motor tremor and what it tells us about mechanisms underlying compensation for fixational eye movements**

G M Wallis (School of Human Movement Studies, University of Queensland, Brisbane, QLD 4072, Australia; e-mail: gwallis@hms.uq.edu.au)

Evidence is presented for the influence of fixational eye movements on visual perception. These eye movements are continuous and of high frequency, suggesting that they are best categorised as ocular motor tremor rather than as drift or microsaccades. Detection of these eye movements manifests itself in the form of a perceptual bias in the grouping of grids of elements in which an imperceptible temporal offset (12 ms) in the presentation of selected elements leads to them being grouped perceptually. A study of eye movements during stimulus presentation revealed that this bias is correlated with eye movement amplitude, indicating that small fixational eye movements cause the temporal offsets to generate spatial disruption of the perceived grid, suggesting that motion compensation has failed in this case. The results reveal that even the smallest category of fixational eye movements can affect perception. It also guides models of motion compensation. The failure of the observers to compensate for their own eye movements implies that either: (i) a model based on efference copy mechanisms is limited to the spatial accuracy of microsaccades, or (ii) the motion estimation integration time window associated with image-based compensation mechanisms must lie outside the spatiotemporal window afforded in these experiments.

[Supported by the Australian Research Council and the Max Planck Society.]

◆ **Poor binocular yoking of the saccades independently from reading in dyslexic children**

Z Kapoula, M P Bucci¶, R Ganem¶, S Poncet¶, D Gintautas§, D Brémond-Gignac# (Iris Group [¶ LPPA UMR 7152], CNRS–Collège de France, 11 place Marcelin Berthelot, F 75005 Paris, France; §Department of Radio-Engineering, University of Siauliai, Studentu Street 50, LT 3031 Kaunas, Lithuania; #Hôpital Robert Debré, Service d'OPH, 48 boulevard Sérurier, F 75019 Paris, France; e-mail: zoi.kapoula@college-de-france.fr)

Fine binocular yoking of saccades is essential for single vision of the words during reading; yoking is learned with age, particularly during reading acquisition. We examined the quality of binocular coordination in dyslexic and non-dyslexic children in three different tasks: during reading of a single word, during free exploration of cubist paintings, and during fixation of a single target. The results show poor yoking of saccades in dyslexics; particularly yoking is worst during free exploration relative to word reading or to single target. In contrast, in non-dyslexics yoking of saccades is good regardless of the task. Thus, poor saccade yoking in dyslexics occurs independently of reading and reflects immaturity of ocular motor learning. Loose yoking is tolerated as it does not interfere with pictorial perception; yet binocular training of saccades in free exploration could be useful to reinforce yoking and render it context-independent as is the case in non-dyslexics.

◆ **Independent effects of saccadic adaptation on spatial localisation before and during saccades**

K Georg, M Lappe (Westfälische Wilhelms-Universität, Psychologisches Institut II, Fliednerstrasse 21, D 48149 Münster, Germany; e-mail: kgeorg@psy.uni-muenster.de)

Short-term saccadic adaptation induces a shift of perceived localisation of objects flashed early before the saccade, and a compression towards saccade landing position of objects flashed immediately at saccade onset (Awater et al, 2005 *Journal of Neurophysiology* **93** 3605–3614). We tested whether the early-presaccadic shift and the peri-saccadic compression are independent or related processes. In our experiment, subjects had to indicate the perceived location of briefly presented stimuli after saccadic adaptation. Because the strength of peri-saccadic compression depends on stimulus contrast, we performed experiments with two different contrast conditions. The first condition yielded large peri-saccadic compression, the second yielded no peri-saccadic compression. The early-presaccadic shift and saccadic compression proved to be independent of each other. Early-presaccadic shift occurred similarly in the conditions with and the conditions without peri-saccadic compression. Peri-saccadic compression, when present in a condition, was additive to the early-presaccadic shift. Our results clarify the time course of the adaptation-induced presaccadic shift and have implications regarding the possible mechanisms of both effects.

[Supported by the DFG LA952/3.]

Friday

◆ Automatic detection and characterisation of microsaccades

M Holschneider, C Paladini, R Kliegl¶, R Engbert¶ (Department of Mathematics, University of Potsdam, 10 am Neuen Palais, D 14469 Potsdam, Germany; ¶ Department of Psychology, University of Potsdam, POB 601533, D 14415 Potsdam, Germany; e-mail: hols@math.uni-potsdam.de)

Fixational eye movements occur unconsciously and involuntarily during fixations. The fast component of fixational eye movements is due to microsaccades, which occur at a rate of about one per second. To characterise and automatically detect the microsaccades is a long-standing research problem. From a mathematical point of view, microsaccades behave like singularities through a wide range of scales. Here, we applied the continuous wavelet transform to detect these singularities and used statistical standard techniques to characterise their local geometry. We show that different subgroups of microsaccades with similar properties exist. Furthermore, these results are used to derive an alternative procedure for the detection and classification of microsaccades.

◆ Eye-movement control: From reading to visual search

H A Trukenbrod, R Engbert (Computational Neuroscience, Department of Psychology, University of Potsdam, PO Box 601553, D 14415 Potsdam, Germany; e-mail: truken@uni-potsdam.de)

During most visual activities our eyes perform a rather complicated pattern of fixations and saccades. Nonetheless, important phenomena related to the coupling of spatial and temporal control of eye movements have been reported for normal text reading, eg the preferred landing site, the saccadic range error, the optimal viewing position and the inverted optimal viewing position. Here, we investigate if these eye-movement patterns can be found in a visual-search task. In a new search paradigm subjects fixated a number of symbols in a predefined order until they had found the target symbol. Our results show that, during visual search, saccades tend to land on a preferred landing site and the landing site distributions depend on the launch site of the previous saccade. Furthermore, refixation probability and fixation durations alter with the current fixation position. We conclude that these effects are not unique to reading but rather represent generic behaviour in eye-movement control.

TESTING OF VISUAL FUNCTION

◆ ON and OFF activity of the cone system

A M Shamshinova, M A Arakelian, A A Kazaryan¶ (Moscow Helmholtz Research Institute of Eye Diseases, Sadovaya-Chernogryasskaya 14/19, 105062 Moscow, Russia; ¶ Moscow Clinical Hospital No.83 of FMBA, Orekhovy blvd 28, Moscow, Russia; e-mail: shamshinova@ophthalmology.ru)

A new method of contrast sensitivity evaluation at each point of the visual field is suggested on the basis of neurophysiology of the retina (MBN, Russia) to determine whether it could be used for investigation of ON and OFF cone system channels. The intensity of achromatic stimuli increased gradually from darker to brighter than the background on the colour monitor. The difference between stimulus and background was evaluated by absolute magnitude of sensorimotor reaction time (RT). The results were analysed by the ratio of RT to the stimulus brightness. Two hundred patients with optic neuropathy and retinopathy of different origins were investigated. In contrast to normal subjects, an increase of the RT was detected for stimuli darker than the background in patients with initial optic neuropathy of different origins. An increase of RT for stimuli lighter than the background was found in macular pathologies and retinopathies. With the development of a pathological process in the optic nerve and the retina a decrease of sensitivity of ON and OFF cone system was detected with an increase of the RT. We hope that the investigation of the functional topography of the ON and OFF channels will reveal new pathology mechanisms explaining visual loss in various optic-nerve and retinal diseases.

◆ Objective measurements of visual acuity

S A Koskin, A Harauzov¶, E V Boiko, A F Sobolev, Y E Shelepin¶, E G Trufanov, V A Fokin, A V Sevastjanov, V N Malahovskij (Department of Ophthalmology, Military Medical Academy, Lebedeva 6, 194044 St Petersburg, Russia; ¶ Pavlov Institute of Physiology, Russian Academy of Sciences, nab. Makarova 6, 199034 St Petersburg, Russia; e-mail: koskin@mailbox.alkor.ru)

The aim of this study was an objective determination of the visual acuity by a combination of two methods: visual evoked potentials and fMRI. Stimuli were Gabor gratings with different spatial frequencies, presented one at a time or organised into a matrix. Responses were recorded to the onset of the stimulus or to the rotation of each Gabor patch. In electrophysiological experiments we used a universal method of visual stimulation and EEG processing (in particular, with ICA decomposition) to minimise errors due to individual differences in the functioning of

the visual system. As a result, a correlation of 0.74 and a logarithmic dependence were obtained between spatial resolution measured by electrophysiological and psychophysical methods. fMRI experiments revealed different activations of visual areas in patients with different refraction and visual acuity. Therefore, with the help of visual evoked potentials and the fMRI signal it is now possible to determine objectively the visual acuity in humans independently of their responses.

◆ **1-D versus 2-D in DB at ECVP**

D P Carey, A Sahraie, C T Trevelyan, L Weiskrantz¶ (Vision Research Laboratories, School of Psychology, University of Aberdeen, Aberdeen AB24 2UB, Scotland, UK; ¶Department of Experimental Psychology, University of Oxford, South Parks Road, Oxford OX1 3UD, UK; e-mail: d.carey@abdn.ac.uk)

Blindsight in the cortically blind refers to residual visual processing of stimuli presented within the field defect. The earliest reports of blindsight were for manual and saccadic localisation of targets briefly flashed in the blind field. Such localisations are commonly thought to depend upon the superior colliculus/pulvinar and/or occipito-parietal cortex of the so-called dorsal stream, which continue to receive visual afferents after geniculostriate damage. Remarkably, localisation experiments have only varied target position in one dimension along either a horizontal or oblique meridian through the blind field. If this aspect of blindsight is mediated by the intact structures using the circuitry normally associated with saccades and reaching, then localisation to 2-D or even 3-D targets should remain intact. We have investigated this possibility with the well studied patient DB with both saccadic and manual localisation tasks. Remarkably, although his manual localisation to targets varied in 2-D conditions was as good as in 1-D conditions, saccadic localisation was substantially poorer for the targets varied in 2-D. These perplexing results are discussed in relation to the multiple coordinate representations for movement.

[Supported by BBSRC Grant BBS/B/05389 to DPC and AS.]

◆ **Optimisation of dark adaptation for specialists who work in different light conditions**

E V Boiko¶, V F Chernush, D I Rogovanov, S A Koskin¶ (¶Department of Ophthalmology, Military Medical Academy, Lebedeva 6, 194044 St Petersburg, Russia; e-mail: boiko@mailbox.alkor.ru)

The purpose of the study was to find an optimal way for dark adaptation. In the first set of experiments, visual acuity and contrast sensitivity were measured on twenty-six healthy men under different lighting conditions (160–200 lux), during first minutes after the light was switched on, with different optical filters: red, green–yellow, neutral, and dark-brown of various densities. In the second set, after 20 min of dark adaptation (1 lux) the same measurements were made in darkness, or in illumination by light filtered by same optical filters. When high-density filters were used, contrast sensitivity decreased substantially. After adaptation in red light and test in low light (1 lux) there was a significant decrease of contrast sensitivity at high frequencies (to the level of 5%–30% from normal); the same picture was observed with all optical filters except dark-brown. With this filter the contrast sensitivity at high frequencies was higher than 85%; similar results were obtained after 20 min of dark adaptation. Adaptation with dark-brown filters is more effective than traditional adaptation in red illumination. This method is advisable for specialists who need quick high visual efficiency in dark after exposure to ordinary illumination.

◆ **Magnocellular impairment drives size distortion in hemispatial neglect**

M Harvey, S H Butler, C J H Ludwig¶, K Muir§, I Bone§, G Duncan#, I D Gilchrist¶, I Reeves# (Department of Psychology, University of Glasgow, 58 Hillhead Street, Glasgow G12 8QB, Scotland, UK; ¶Department of Experimental Psychology, University of Bristol, 12A Priory Road, Bristol BS81TU, UK; §Department of Neurology [#Stroke Unit], Southern General Hospital, 1345 Govan Road, Glasgow G51 4TF, Scotland, UK; e-mail: M.Harvey@psy.gla.ac.uk)

Recent work on patients with hemispatial neglect indicates that such patients misperceive objects in that a leftward stimulus appears relatively smaller than a rightwardly placed one. Here we examined the relative contributions of magnocellular (M-) and parvocellular (P-) pathways to this impairment. Ten patients and fourteen age-matched controls participated in a line-length judgment task, indicating whether the left or right of two horizontally placed lines was either longer or shorter. Lines were designed to predominantly stimulate either M- or P-systems. M-stimuli were defined solely by luminance and P-stimuli by colour, with added noise to abolish luminance cues. All ten patients tested showed some underestimation of object length in their left hemispace, but the effect was particularly pronounced for lines defined by luminance. This suggests a dominant contribution of the M-pathway to this impairment. We relate these findings to the differential inputs of M- and P-systems into the dorsal and ventral streams of higher-level vision.

[Supported by the Royal Society (grant no: 24498).]

Friday

◆ **Temporal visual resolution in normal and pathological oculo-ocular reactions after severe ocular trauma**

M V Zueva, I V Tsapenko, V A Chernookova¶, E N Verigo¶, V V Rozhentsov§ (Laboratory of Clinical Physiology of Vision [¶ Department of Ocular Trauma and Reconstructive Surgery], Moscow Helmholtz Research Institute of Eye Diseases, 105064 Moscow, Russia; §Department of Projecting, Mari State Technical University, Yoshkar-Ola, 424031 Mari-El, Russia; e-mail: zueva.mv@mtu-net.ru)

Our object was to determine alterations of temporal resolution in fellow eyes after a severe ocular trauma. We tested temporal visual properties of fellow eyes in thirty healthy subjects and seventy-nine patients who have undergone severe ocular trauma—eleven with sympathetic ophthalmia (SO)—by using two psychophysical methods: 'CFF-inertia' (ICFF) and 'differential CFF' (DCFF). ICFF was used to determine a threshold time of separate colour stimulus sensation in each flash clip—the time of inertia (Ti). DCFF was used to determine a minimal time difference between two clips of double stimuli of different frequencies (D). We found a significant increase of D for blue and green stimuli and of Ti for blue stimuli. More pronounced disturbances were characteristic in temporal resolution of blue light in the patients with SO. The lowering of temporal integration of S-cone pathways may be related to reinforcement of the inhibition process in higher nervous system as a reflection of general adaptation syndrome. We conclude that specific changes in inertness and differential flicker sensitivity of visual system in contralateral eyes after severe ocular trauma can distinguish a normal fellow eye reaction from a pathological one and determine a high-risk of SO development.

◆ **Accurate measurement of visual acuity: The predicament caused by accommodation mechanisms**

G I Rozhkova, V S Tokareva (Institute for Information Transmission Problems, Russian Academy of Sciences, Bolshoi Karetnyi 19, 127994 Moscow, Russia; e-mail: gir@iitp.ru)

Precise accommodation for fine focusing of the test images on the retina is one of the important conditions necessary to reveal the true limit of visual resolution inherent to a subject. According to the available data (eg Owens, 1980 *Vision Research* **20** 159–168; Mathews and Kruger, 1994 *Vision Research* **34** 1965–1980), the human accommodation mechanisms are functioning optimally in the range of spatial frequencies corresponding to the optimum of the contrast sensitivity function: 3–5 cycles deg⁻¹. At the same time, visual resolution of many children and young adults with high visual acuity corresponds to the frequencies of 40–70 cycles deg⁻¹. Thus, unfortunately, the miniature optotypes needed to measure such high visual acuity seem to be poor stimuli for accommodation. As a consequence, during measurements, accommodation level could fluctuate and move to the resting accommodation point causing degradation of the retinal image and reducing probability of correct responses. To provide sustained fine focusing of the miniature test stimuli during visual acuity measurements, it seems rational to use some additional stimuli for effective accommodation. Indeed, in our preliminary experiments, employing special background patterns for sustained accommodation, we revealed a significant positive effect of such background in a number of schoolchildren with certain acuity–distance characteristics.

[Supported by RFBR grant 04-04-48894.]

◆ **Blindsight and visual rehabilitation in the cortically blind**

A Sahraie, C T Trevelyan, M-J MacLeod¶, J Olson¶, L Weiskrantz (Vision Research Laboratories, School of Psychology [¶ School of Medicine and Therapeutics], University of Aberdeen, Aberdeen AB24 2UB, Scotland, UK; e-mail: a.sahraie@abdn.ac.uk)

Lesions of the occipital cortex can result in areas of cortical blindness affecting the corresponding regions of the patient's visual field. The traditional view is that, aside from limited, acute and spontaneous recovery, such areas of blindness are absolute and permanent. It has been found, however, that within such field defects some residual visual capacities may persist. These residual capacities are termed blindsight. Using both psychophysical and pupillometric techniques we investigate residual spatial properties within blindfield of a cohort of cortically blind patients ($n = 16$). Using forced-choice detection of spatially and temporally modulated gratings we demonstrated the presence of a narrow spatial channel of processing in 12 of the cases investigated. The pupillometric data are also in agreement with the psychophysical findings. On the basis of the characteristics of residual visual processing, a visual rehabilitation protocol has been devised incorporating repeated stimulation of cortically blind areas. In a group of 12 patients, an increased visual sensitivity within the field defect was demonstrated. These findings suggest that (a) blindsight in cases of cortical blindness may not be a rare phenomenon, and (b) repeated stimulation based on appropriate visual stimuli may result in improvements in visual sensitivities.

[Supported by Chief Scientist Office, Scottish Executive, CBZ/4/30.]

FUNCTIONAL MAPPING

◆ Are activations in the salience map short-lived?

M Donk (Department of Cognitive Psychology, Vrije Universiteit Amsterdam, van der Boechorststraat 1, NL 1081 BT Amsterdam, The Netherlands; e-mail: w.donk@psy.vu.nl)

The salience of an object is typically determined by its local feature contrast relative to the surrounding objects. Most models of visual search assume that salience is represented in our visual system in some sort of location-based salience map. Competition among neurons in this map yields a single winning location that corresponds to the next attended location. If the location is inhibited, the system automatically shifts to the next most salient location and so forth. Implicitly, models adhering to this idea assume that the visual system is able to continuously hold information about the relative salience of objects in the visual field. In the present study we manipulated the relative salience of individual elements in homogenous displays. Participants had to indicate the location of the most salient element. The results demonstrated that, even though participants are very good at this task with short presentation durations, with longer presentation durations performance drops considerably. These results suggest that salience is only transiently represented in the visual system, suggesting that its role in visual selection can only be short-lived. The results are discussed in terms of current models of visual search.

◆ Overcomplete representation for fast attentional selection by bottom – up salience in the primary visual cortex

L Zhaoping (Department of Psychology, University College London, Gower Street, London WC1E 6BT, UK; e-mail: z.li@ucl.ac.uk)

Efficient coding [Barlow, 1961, in *Sensory Communication* Ed. W A Rosenblith (Cambridge, MA: MIT Press) pp 217–234] to obtain independent input components has been shown to explain single cell properties, eg orientation selectivity, in primary visual cortex (V1). However, V1 neurons represent inputs overcompletely, carrying correlated rather than independent signals. In particular, at any spatial location and scale, two neurons tuned to two different orientations would be sufficient to completely represent input orientations; yet many more V1 neurons tuned to different orientations are actually used. Recently, it has been proposed that V1 creates a bottom – up salience map, such that the receptive field location of the most active neuron is most likely to attract gaze, eg via superior colliculus, and receive further processing (Li, 2002 *Trends in Cognitive Sciences* 6 9–16). I propose that the overcompleteness serves faster selection by signalling the salience of any location explicitly in a single cell, rather than implicitly in a group of cells. If V1 had an efficient code with fewer neurons, post-processing of V1 outputs would be necessary to compute and extract salience explicitly, eg to obtain salience due to an orientation not explicitly signalled by a V1 neuron, thus requiring extra time.

[Supported by the Gatsby Charitable Foundation.]

◆ Salience from combined feature contrasts: Evidence for feature-specific salience interaction suggestive of V1 mechanisms

A R Koene, L Zhaoping (Department of Psychology, University College London, 26 Bedford Way, London WC1H 0AP, UK; e-mail: a.koene@ucl.ac.uk)

A target can be salient against a background of distractors owing to a unique feature such as colour (C), orientation (O), motion direction (M), or combinations of them. Using subjects' reports comparing saliences between two stimuli, Nothdurft (2000 *Vision Research* 40 1183–1201) found that combining features increases salience. Since salience serves visual selection rather than discrimination, reaction times (RTs) provide a more direct measure. Krummenacher et al (2002 *Journal of Experimental Psychology: Human Perception and Performance* 28 1303–1322) measured RTs for detecting targets unique in O, C, or combination O + C, revealing that O + C requires shorter RTs than predicted by a race model, which models RT as an outcome of a race between two independent decision processes on O or C only. We measured RT to locate targets unique in O, C, M, or their combinations. Significant (by *t*-test) violation of the race model by shorter RTs was found in O + M and C + O but not C + M. These results are consistent with some V1 neurons being conjunctively selective to O + M, others to C + O but almost none to C + M (Horwitz and Albright, 2005 *Journal of Vision* 5 525–533; Li, 2002 *Trends in Cognitive Sciences* 6 9–16). Comparing shortest RTs in the single versus double feature conditions corroborated this finding.

[Supported by the Gatsby Charitable Foundation.]

Friday

◆ **Brain oscillations—indicators for serial processing in inefficient visual search?**

J Palix, C-A Hauert, U Leonards (Faculty of Psychology and Sciences of Education, University of Geneva, 40 boulevard du Pont d'Arve, CH 1211 Geneva 4, Switzerland; e-mail: julie.palix@pse.unige.ch)

The electroencephalographic (EEG) N2pc component, originally suggested as neurophysiological correlate of visuospatial shifts of attention, seems rather related to target detection and distractor suppression. This reopens the debate whether a shifting focus of attention, and thus serial processing, exists in inefficient visual search. Reasoning that search rate for target-absent trials should indicate the speed with which attention can be shifted for a given search type, we here investigated whether repetitive EEG frequency components correlate with search rate in an inefficient search task. Search rate was about 67 ms/item for target-present (TP) trials and 186 ms/item for target-absent (TA) trials. Wavelet analysis of response-locked EEGs revealed significant differences in EEG beta-frequency bands (12–21 Hz) between TP and TA conditions, moving in time from frontal to central electrodes, presumably related to decision-making. More importantly, low-frequency modulations (~7 Hz) of response-locked EEG gamma-frequency bands (44–75 Hz) over posterior electrodes correlated with search rate for TA trials. Given that gamma-oscillations are thought to be related to visual processing and attention, such EEG modulations might indeed reflect a shifting focus of attention, and thus serial processing, in inefficient visual search; alternative interpretations are also discussed.

[Supported by the Faculty of Psychology and Sciences of Education, University of Geneva, Switzerland.]

◆ **Functional organisation for biological motion in the fusiform gyrus**

L Michels, M H E de Lussanet, R J Seitz¶, M Lappe, R Kleiser§ (Psychological Institute II, Westfälische Wilhelms-Universität Münster, Fliehdnerstrasse 21, D 48149 Münster, Germany; ¶ Brain Imaging Center West [BMBF], Heinrich-Heine-Universität Düsseldorf, Moorenstrasse 5, D 40225 Düsseldorf, Germany; § Institute of Neuroradiology, University Hospital Zürich, Frauenklinikstrasse 10, CH 8091 Zürich, Switzerland; e-mail: michelsl@uni-muenster.de)

Humans easily recognise walking and running from point lights attached to the major joints of an otherwise invisible body (Johansson, 1973 *Perception & Psychophysics* **14** 201–211). fMRI studies have shown that regions of the fusiform gyrus (FG) and the superior temporal sulcus (STS) respond stronger to biological motion than to scrambled controls (Grossman et al, 2002 *Neuron* **35** 1167–1175). Different visual categories are represented in different regions of the FG (Tarr and Gauthier, 2000 *Nature Neuroscience* **3** 764–769). In monkeys, different views of human faces activated different regions in the inferotemporal cortex (Wang et al, 1998 *Neuroscience Research* **32** 33–46), which is supposed to be homologous to human FG. In the present study, we investigated, using fMRI, whether human FGs also possess a functional map for different orientations of biological motion. Leftward-facing point-light walkers activated a different region of the FG in both hemispheres than rightward-facing ones. We found this in a single-subject analysis. Such a functional map was not present in STS. Our findings suggest that the FG not only is organised in different regions for different visual categories, but also that different views of the same object activate different regions.

[Supported by the German Science Foundation, the German Federal Ministry of Education and Research BioFuture Prize, and the EC Projects ECo Vision and Eurokinesis.]

◆ **Frontal influences on human retinotopic visual cortex revealed by combining TMS with fMRI and psychophysics**

C C Ruff¶, E D Freeman, F Blankenburg¶, O Bjoertomt, S Bestmann¶, J-D Haynes¶, G Rees¶, J Driver¶ (Institute of Cognitive Neuroscience, Department of Psychology, University College London, 17 Queen Square, London WC1N 3AR, UK [¶ also Wellcome Department of Imaging Neuroscience, 12 Queen Square, London WC1N 3BG, UK]; e-mail: c.ruff@ucl.ac.uk)

Regions in human frontal cortex may have modulatory top-down influences upon retinotopic visual cortex, but to date neuroimaging methods have only provided indirect evidence for functional interactions between these remote but interconnected brain regions. Here we combined functional magnetic resonance imaging (fMRI) with concurrent transcranial magnetic stimulation (TMS) to show that stimulation of the human frontal eye-field produces a characteristic pattern of activity changes in retinotopic visual areas V1–V4, with functional consequences for visual perception. Increased frontal TMS intensity led to activity increases for retinotopic representations of the peripheral visual field, but to activity decreases for the central field, in retinotopic visual cortex. These frontal influences upon visual cortex applied in a top-down manner, regardless of bottom-up activity due to visual input, and were not present during TMS to a vertex control site. Finally, the pattern of effects on retinotopic visual cortex led to a new behavioural

prediction that we confirmed in a psychophysical experiment, showing that TMS to the frontal site (again compared with vertex) enhances perceived contrast for peripheral relative to central visual stimuli. Our results show directly that the human frontal eye-field is capable of modulating activity in retinotopic visual cortex, with functional consequences for visual perception. [Supported by the Wellcome Trust and the BBSRC(UK).]

ATTENTIVE VISUOMOTOR PROCESSES

- ◆ **Increased attention to tactile stimuli modulates the amygdala response to visual affective stimuli**
A N Rich¶, M A Williams§, F McGlone#, R Cunnington‡, J B Mattingley (Cognitive Neuroscience Laboratory, School of Behavioural Science, University of Melbourne, VIC 3010, Australia [¶ also Visual Attention Laboratory, Brigham & Women's Hospital/Harvard Medical School, Suite 170, 64 Sidney Street, Cambridge, MA 02143, USA]; § McGovern Institute for Brain Research, Massachusetts Institute of Technology, Cambridge, MA 02139, USA; # Unilever Research Laboratories, Port Sunlight, UK; ‡ Howard Florey Institute, University of Melbourne, VIC 3010, Australia, and Brain Research Institute, Austin & Repatriation Medical Centre, Melbourne, Victoria, Australia; e-mail: rich@search.bwh.harvard.edu)

Recent neuroimaging studies have claimed that the amygdala responds preferentially to affective facial expressions regardless of the focus of attention. In contrast, other regions of cortex, such as the 'fusiform face area', are strongly modulated by attention, responding less when attention is occupied by non-preferred stimuli. In these previous experiments, both the critical stimuli and the attentional manipulations were within a single sensory modality. Here, we used fMRI to record changes in the BOLD signal in response to affective faces while attention was manipulated within the tactile domain. Participants performed a gap-discrimination task on a stream of air delivered to each index finger. The difficulty of the gap task was titrated to form high and low attentional load conditions. Simultaneously, participants viewed affective or neutral faces, interleaved in a block design. The amygdala response to fearful faces reduced as the attentional load of the tactile task increased, following the typical pattern of attention-dependent processing of category-specific cortex. These data demonstrate that the amygdala response to affective stimuli is not immune to manipulations of attention but depends critically on the extent to which attention is deployed within the relevant modality.

[Supported by Unilever Research Laboratories; National Health & Medical Research Council of Australia; Menzies Foundation.]

- ◆ **Eye velocity adaptation to peripheral motion during pursuit eye movements**
M Spring, K R Gegenfurtner (Department of Psychology, Justus Liebig University, Otto-Behagel-Strasse 10F, D 35394 Giessen, Germany; e-mail: miriam.spring@psychol.uni-giessen.de)

During smooth-pursuit eye movements, eye velocity is adapted to changes in target velocity (Kowler and McKee, 1987 *Vision Research* 27 993–1015). Horizontal eye velocity also changes in the presence of a stationary or horizontally moving textured background (Kimmig et al, 1992 *Journal of Neurophysiology* 68 2147–2164). We asked how peripheral motion information is used for oculomotor control when a visual context moves vertically during horizontal pursuit. Human observers were instructed to track a small, medium-contrast Gaussian dot, moving horizontally at 11.5 deg s^{-1} . Above and below the target trajectory we presented two horizontally oriented sine-wave gratings. The visual context was stationary upon pursuit initiation, and moved upwards or downwards during the steady-state phase of the eye movement for 300 ms. We recorded eye position with a dual-Purkinje-image eye tracker at 500 Hz. While vertical context motion did not affect horizontal eye velocity, vertical eye velocity deviated in the direction opposite to grating motion by 1 deg s^{-1} at $\sim 170 \text{ ms}$ after context-motion onset. The vertical deviation also occurred with only one grating moving, and increased up to 2 deg s^{-1} with higher context velocity. Apparently, eye velocity adapts to changes in direction and velocity of a vertically moving context during horizontal pursuit.

[Supported by Deutsche Forschungsgemeinschaft Graduate Program 'Brain and Behaviour' (DFG 885/1), Forschergruppe 'Perception and Action' (DFG 560).]

- ◆ **Evidence from converging paradigms for posterior cortical involvement in response inhibition**
S H Butler, C J H Ludwig¶, I D Gilchrist¶, K Muir§, I Bone§, I Reeves§, G Duncan§, M Harvey (Department of Psychology, University of Glasgow, 58 Hillhead Street, Glasgow G12 8QB, Scotland, UK; ¶ Department of Experimental Psychology, University of Bristol, 12A Priory Road, Bristol BS8 1TU, UK; § Stroke Unit, Southern General Hospital, Glasgow G51 4TF, UK; s.butler@psy.gla.ac.uk)

People often scan the environment for particular items such as a friend in a crowd, and in many such situations the deployment of attention and eye movements will be under voluntary control.

Friday

However, the eyes can also be captured involuntarily by salient events, such as the sudden appearance of a new object, even when these events are irrelevant to the goal of the individual. We have studied the ability of patients with unilateral posterior cortical lesions, to inhibit unwanted, but prepotent, saccadic eye movement responses to abrupt onset stimuli in oculomotor capture and anti-saccade paradigms. Relative to controls, these patients show overall impaired control in response inhibition. Of particular interest is the absence of spatial modulation in the patients inability to inhibit saccades in the anti-saccade task. Response inhibition is typically associated with the frontal lobes, but our data further suggest the involvement of posterior structures as part of a larger cortical network.

[Supported by the Royal Society of Edinburgh/Lloyds TSB studentship, EPSRC, and the Royal Society.]

◆ **How well can neighbouring distractors be ignored when generating saccades to targets?**

J M Findlay, H I Blythe (Department of Psychology, University of Durham, South Road, Durham DH1 3LE, UK; e-mail: j.m.findlay@durham.ac.uk)

The saccadic orienting system operates continually and efficiently to transfer the gaze to new locations in the visual field. We present data to show how well targets can be selected during saccadic scanning. In a previous study (Findlay and Brown, 2006 *Vision Research* **46** 216–227) we required observers to carry out a search task that involved scanning through each one of a set of identical items. Saccadic accuracy was good in general but was substantially decreased when targeting an item with a second item at a nearby location. In the present study we used a simplified task with similar material but gave specific instructions about targeting. In this situation, saccadic accuracy remained high, except when the neighbouring distractor was at a location along the same axis as the trajectory of the planned saccade. We conclude that attentional processes can achieve accurate target selection for saccades but these may not be operative in the automatised routines characteristic of everyday scanning.

◆ **Attentional modulation of sensorimotor processes in the absence of perceptual awareness**

P Sumner (School of Psychology, Cardiff University, PO Box 68, Cardiff CF1 3XA, Wales, UK; e-mail: sumnerp@cardiff.ac.uk)

Attention is generally considered to be inextricably linked with conscious awareness, but recent evidence suggests that attention can modulate the effects of stimuli that remain invisible. Presumably, attention brings subthreshold perceptual representations closer to conscious threshold. However, there is also the possibility that attention may modulate neural processes that are entirely separate from those supporting conscious perception—sensorimotor mechanisms that do not create awareness, however much they are enhanced. In support of this idea, it was found that attentional cueing can modulate the behavioural response to invisible stimuli in a way that is distinct from enhancing their visibility. A masked-prime paradigm that produces negative or positive priming depending on the perceptual strength (duration) of the prime was employed. Attention was found to enhance both negative and positive priming, and also increase the likelihood of detecting the prime (ie boosting perceptual strength). Crucially, the pattern of attentional influence on priming could not be explained by the attentional modulation of the prime's perceptual strength, but was predicted by a direct attentional influence on the non-conscious priming process itself. Therefore, in addition to regulating what we perceive, attention seems to influence our behaviour through sensorimotor processes that are not involved in conscious awareness.

◆ **Can the purpose of inspection influence the potency of visual salience in scene perception?**

T Foulsham, G Underwood (School of Psychology, University of Nottingham, Nottingham NG7 2RD, UK; e-mail: lpxtf@psychology.nottingham.ac.uk)

Efficient perception of natural scenes depends on sampling the most relevant details by well-targeted shifts of attention. Salience map models predict that this sampling is controlled by a preattentive representation of the scene in terms of low-level feature discontinuities. These models have found some support, but an increasing emphasis on the task viewers are performing implies that salience must combine with cognitive demands to guide the eyes efficiently. We examined eye movements to objects in photographs while viewers performed a memory encoding task or one of two search tasks. The objects depicted in the scenes had known salience ranks according to the model proposed by Itti and Koch (2000 *Vision Research* **40** 1489–1506). Participants fixated higher salience objects sooner and more often than lower salience objects, but only when memorising scenes. Salience had no effects when searching for a target defined by category or exemplar. The results suggest that salience maps are not used to guide the eyes in these tasks and that cognitive override by task demands can be total.

◆ **Saccades are faster when accompanied by a hand movement—effect of shared goals, shared trajectories, or both?**

K Drewing, M Spering (Institute for Psychology, Giessen University, Otto-Behaghel-Strasse 10F, D 35394 Giessen, Germany; e-mail: Knut.Drewing@psychol.uni-giessen.de)

When combining a saccade towards a visual target and a concurrent hand movement, the saccade is faster than when it is executed in isolation (Snyder et al, 2002 *Journal of Neurophysiology* **87** 2279–2286). This coordination advantage may result from specifying the same movement goal for hand and eye, or it may be due to the shared trajectories of hand and eye. Participants ($N = 16$) in our experiment made a saccade in isolation, or a saccade accompanied by a pointing movement. Saccades and pointing movements aimed at the same or different goals, and followed similar or different trajectories (ie in the same or opposite direction). Start and target points for the movements were visually specified, the 'go' signal was auditory. Simultaneous pointing movements increased saccadic peak velocity only when eye and hand followed similar trajectories—independently of whether eye and hand shared the movement goal. Saccade latency did not reliably differ between conditions. These results suggest that a common trajectory of eye and hand produces the coordination advantage, and, thus, that the main sequence of saccadic eye movements is altered by parallel hand movements.

◆ **On the limited role of target onset in the gap task: Support for the motor-preparation account**
M Rolfs, F Vitu¶ (Department of Psychology, University of Potsdam, PO Box 601 553, D 14415 Potsdam, Germany; ¶ Laboratoire de Psychologie Cognitive, CNRS, Université de Provence, Centre St Charles, Bâtiment 9, Case D, 3 place Victor Hugo, F 13331 Marseille Cedex 3, France; e-mail: rolfs@uni-potsdam.de)

When a fixation stimulus disappears prior to the onset of a peripheral saccade target (gap condition), mean saccadic reaction times are usually very low, as compared to a situation where the fixation stimulus remains on the screen while the target appears (overlap condition). This reduction in response latency is commonly referred to as the gap effect. We used a modified gap paradigm, and were able to produce a very strong gap effect in the absence of a peripheral target onset. In addition, we showed for the first time that target onset differentially modulates saccade latencies in the two conditions. Target onset significantly reduced saccade latency in the overlap but not in the gap condition. This result suggests that the computation of saccade amplitude was advanced in the gap task, thus supporting the motor-preparation assumption proposed by Paré and Munoz (1996 *Journal of Neurophysiology* **76** 3666–3681).

MOTION PERCEPTION

◆ **Measuring motion illusion strength in op art paintings**

J M Zanker, U Leonards¶ (Department of Psychology, Royal Holloway University of London, Egham TW20 0EX, UK; ¶ Department of Experimental Psychology, University of Bristol, 12A Priory Road, Bristol BS8 1TU, UK; e-mail: j.zanker@rhul.ac.uk)

Using simple black and white patterns, Op artists create vivid sensations of movement which spawned a lively scientific debate about visual processing mechanisms underlying motion illusions in static images. Recent studies point in the direction of a rather simple account in terms of involuntary eye movements, which lead to characteristic motion interference patterns (Zanker and Walker, 2004 *Naturwissenschaften* **91** 149–156). We developed a new method to quantify the strength of the illusion for synthetic 'riloids' that were inspired by some of Bridget Riley's paintings, to replace the unreliable rating scale used previously. Observers compared in a 2AFC paradigm the motion sensation for a given test stimulus with that for a set of reference stimuli, which were combinations of a riloid and a checkerboard pattern at different contrast ratios. The dominance of the riloid in the compound pattern led to a strong motion illusion, whereas a dominating checkerboard led to a static percept. The continuous variation of illusion strength between these two extremes is utilised to generate psychometric functions, which allow us to compare the illusion strength for different test stimuli. A pilot study of this method found no clear differences between observers suffering from migraine and controls.

◆ **3-D perception from velocity field produced by cyclic display of 3-phase images including one stroke apparent-motion pair**

M Idesawa, X Chen (Graduate School of Information Systems, University of Electro-Communications, 1-5-1, Chofugaoka, Chofu-shi, Tokyo 182-8585, Japan; e-mail: idesawa@is.uec.ac.jp)

A new illusion of unidirectional motion perception from cyclic display of two sequential frames and one blank frame was submitted for the Best Visual Illusion of the Year Contest at ECVP 2005 by Mather (http://www.lifesci.sussex.ac.uk/home/George_Mather/TwoStrokeFlash.htm). We tried to produce a continuous velocity field by the cyclic display of 3 phase images including a correlated

Friday

image pair $\{I_a, I_b\}$ and an independent image $\{I_c\}$; the velocity field $V_f(x, y) = V_{xy}(v_x, v_y)$ is formed, and optic flow can be perceived as a stream along the apparent-motion stroke $D_{xy}(d_x, d_y)$ that results from the difference between the correlated image pair. The magnitude of velocity at position (x, y) is proportional to the apparent-motion strokes and inversely proportional to the display interval (T) of each phase image; the velocity is then estimated as $V_{xy}(v_x, v_y) = D_{xy}(d_x, d_y)/T$. In addition, the direction (polarity) of the velocity field is reversed by changing the cyclic order of the correlated image pair. We designed the correlated image pair with random dots and successfully displayed various types of continuous velocity field. We found that not only motion but also depth, structure, shape, surface, and volume in 3-D space can be perceived almost the same as in a velocity field produced by real motion.

◆ **Asymmetric transfer of the dynamic motion aftereffect between first-order and second-order cues**

A J Schofield, T Ledgeway¶, C V Hutchinson¶ (School of Psychology, University of Birmingham, Edgbaston, Birmingham B15 2TT, UK; ¶ School of Psychology, University of Nottingham, University Park, Nottingham NG7 2RD, UK; e-mail: a.j.schofield@bham.ac.uk)

Recent work on motion processing has suggested a distinction between first-order cues [such as luminance (LM)] and second-order cues [such as contrast modulations (CM) and orientation modulations (OM)]. Although detected independently, both the tilt aftereffect and the contrast reduction aftereffect transfer symmetrically between static LM, CM, and OM cues (Georgeson and Schofield, 2002 *Spatial Vision* 16 59–76; Cruickshank and Schofield, 2005 *Spatial Vision* 18 379–398). We tested for transfer of the dynamic motion aftereffect (dMAE) between LM, CM and OM, matched for visibility and imposed on 1 D, vertical dynamic noise. Observers adapted to 0.5 cycle deg⁻¹ horizontal modulations for 2 min (with 10 s top-ups). Strong within cue dMAEs (as estimated from the modulation-depth ratio required to produce a stationary percept from a pair of superimposed test gratings moving in opposite directions) were found to transfer from LM to CM and OM, and from CM to OM but not from CM to LM, or from OM to CM or LM. Where present, the dMAE was spatial-frequency tuned for LM and CM tests but not for OM. This asymmetric transfer of the dMAE between first-order and second-order cues suggests a processing hierarchy with separation even among the second-order cues.

[Supported by BBSRC Responsive Research Grant (BB/C518181/1) to TL and EPSRC grant (GR/S07254/01) to AJS.]

◆ **The effect of flashing stimuli on the motion perception of remote moving objects**

M Adibi¶, A Ezzati (School of Cognitive Sciences, Institute for Studies in Theoretical Physics and Mathematics (IPM), Niavaran, Tehran, Iran; ¶ also Department of Electrical Engineering, Iran University of Science and Technology, Tehran, Iran; Laboratories for Brain and Cognitive Sciences, Shaheed Beheshti University of Medical Sciences, Tehran, Iran; e-mail: mehdi.adibi@gmail.com)

We used a spatiotemporal weighted averaging model of motion perception in which the perception attributed to the position of a moving object at time t is a function of its positions in a time interval $[t - \alpha, t + \beta]$. To determine the model parameters, we designed a motion reversal paradigm in which two bars at the opposite sides of the screen moved towards each other, and when they met the direction of their motion reversed. The subjects perceived that the motion reversal occurred before the stimuli reached each other. To determine the effect of flashing stimuli, two flashes appeared at the time of motion reversal. The dependence of the perceived misalignment between flashes and the moving stimuli on both pre- and post-flash speed of the moving stimuli indicates that motion perception system is neither predictive as proposed by Nijhawan (1994 *Nature* 370 256–257), nor postdictive as proposed by Eagleman and Sejnowski (2000 *Science* 287 2036–2038), but it uses a time window of ~ 160 ms to calculate the position of moving objects at a time within this interval. Comparison of the results indicates that the flash has no significant effect on both the limits of the time window of integration and the weights

[Supported by the School of Cognitive Sciences, Institute for Studies in Theoretical Physics and Mathematics, Tehran, the Laboratories for Brain and Cognitive Sciences, Shaheed Beheshti University of Medical Sciences, Tehran, and the Iran University of Science and Technology, Tehran.]

◆ **Different coherence thresholds for detecting and localising rotating and radial motion flow patterns**

B M Harvey, O J Braddick (Department of Experimental Psychology, University of Oxford, South Parks Road, Oxford OX1 3UD, UK; e-mail: benjamin.harvey@psy.ox.ac.uk)

In the past, coherence thresholds have been measured for detecting expansion, contraction, and rotation in random-dot patterns. However, subjects' ability to localise the centres of these optic

flow patterns may have an important role in monitoring and control of self-motion. Using a 2AFC method in which the centre of the pattern may lie either side of an implicit reference point, we have determined coherence thresholds for locating the centre with precision ranging from 0.05° upwards. For localisation to $0.5^\circ - 1^\circ$ precision, thresholds are significantly higher than for detection. For precision better than 0.25° , thresholds for localisation rise steeply. The ordering of the respective performance for rotation, expansion, and contraction often changes between detection, coarse localisation, and fine localisation. We discuss these results in relation to computational models of optic flow processing (eg Perrone and Stone, 1998 *Journal of Neuroscience* **18** 5958–5975), and neuropsychological (Beardsley and Vaina, 2005 *Journal of Computational Neuroscience* **18** 55–66) and neuroimaging evidence (Koyama et al, 2005 *Current Biology* **15** 2027–2032) for a cortical area specialised for locating the centre of flow patterns. We suggest that performance at low coherence depends on low-precision global processing mechanisms. At higher coherence, more local mechanisms with a different neuronal population may perform more accurate localisation. [Supported by a Medical Research Council (UK) grant G7908507 and an MRC studentship to BMH.]

◆ **The build-up of a motion-induced mislocalisation effect**

C de'Sperati, G Grimoldi, G Baud-Bovy¶, A Jacomuzzi (Visuomotor Functions Laboratory [¶ Laboratoire di Percezione, Azione e Cognizione—LAPCO], Università 'Vita-Salute' San Raffaele, via Olgettina 58, I 20132 Milan, Italy; e-mail: desperati.claudio@hsr.it)

We showed that saccades directed to a flash displayed next to a stimulus that starts moving at the time of the flash are biased in the direction of motion. We found that the bias increased as a function of latency. To further explore this issue, subjects were trained to make a saccade to the flash in correspondence with the last of a sequence of three beeps. The SOA between the last beep and the flash varied between 100 and 500 ms, thus ensuring a wide range of saccade latencies. While the bias of long-latency (> 400 ms) saccades was quite large (mean directional error: 7.5°), at latencies of 250 ms or less the bias was close to zero. We also showed that the flash position signal was able to fully drive saccadic eye movements already 150 ms after flash presentation, thus ruling out predictive strategies for very-short-latency saccades. In short, the observation that early saccades can be driven by unbiased positional information suggests a progressive build-up of the mislocalisation effect. Our data suggest also that the (illusory) perception of flash position is formed only once the internal representation of motion is completed.

◆ **Speed overestimation in launching and triggering events**

G Parovel, C Casco¶, M Sinico§ (Communication Science Department, University of Siena, piazza San Francesco 8, I 53100 Siena, Italy; ¶ Department of General Psychology, University of Padua, via Venezia 8, I 35131 Padua, Italy; § Department of Psychology, University of Bologna Alma Mater Studiorum, viale Berti Pichat 5, I 40127, Bologna, Italy; e-mail: parovel@unisi.it)

In launching and triggering events [Michotte, 1946/1963 *The Perception of Causality* (London: Methuen)] two objects moving sequentially at speeds V_1 and V_2 are spontaneously described as causally related. We previously showed (Parovel and Casco *Vision Research* under revision) that the speed of the second moving object is largely overestimated when the delay between the two movements is short (40 ms), not when it is long (1040 ms). The ratio between the speed overestimation of the second object (ΔV) and the speed of the first (V_1) is constant in launching, and decreases as V_1 increases in triggering. This dissociation indicates that overestimation follows Weber's law in launching but not in triggering. We ran two experiments in order to understand if speed overestimation is tied to causal perception, or there is overestimation in events without delay that are not causal. In experiment 1 we changed the relative directions of the trajectories, maintaining the delay at 40 ms. Subjects reported no causality and psychometric functions showed no overestimation. Experiment 2, instead, still showed overestimation when the two trajectories are in opposite directions (inverse launching). We conclude that overestimation is specific to perception of causality and cannot be generalised to other consecutive speeds not involving causality.

◆ **Implicit priming of apparent motion**

I M Thornton, C Laloyaux¶, A Cleeremans¶ (Department of Psychology, University of Wales Swansea, Singleton Park, Swansea SA2 8PP, Wales, UK; ¶ Cognitive Science Research Unit, Université Libre de Bruxelles CPI91, Avenue F-D Roosevelt 50, B 1050 Brussels, Belgium; e-mail: i.m.thornton@swansea.ac.uk)

Can dynamic patterns influence behaviour even when the nature of such patterns is unavailable for explicit report? Here, we introduce a new task to examine this question. In the first frame of an apparent motion (AM) sequence, observers were presented with 6 identical, oriented lines, equally spaced around a clock-face display. In the second AM frame, only a single line appeared

Friday

at one of the locations. The location was unpredictable, and the orientation change, relative to the first frame, was systematically varied to alter the perceived direction of rotation, clockwise or counterclockwise. The crucial modification was the addition of an 'internal' prime display. This was inserted between the frames of the AM sequence and consisted of 6 smoothly rotating radial patterns, spatially coincident with the lines. The direction of rotation was individually determined for each pattern. Using the same display, observers completed two tasks in separate blocks: first, to report the perceived direction of apparent motion, ignoring the radial primes; second, to report the direction of the radial prime cued by the second AM frame. Perceived direction of AM was strongly and consistently biased by the prime even though explicit report of its direction was completely at chance.

[Supported by the National Fund for Scientific Research (Belgium) to CL and AC.]

FACE PERCEPTION

◆ The neural correlates of eye gaze adaptation

A J Calder, J D Beaver, E Eger¶, R Jenkins, J Winston¶, R J Dolan¶, R N A Henson
(Cognition and Brain Sciences Unit, Medical Research Council, 15 Chaucer Road,
Cambridge CB2 2EF, UK; ¶ Wellcome Department of Imaging Neuroscience,
12 Queen Square, London WC1N 3BG, UK; e-mail: andy.calder@mrc-cbu.cam.ac.uk)

We used a perceptual fMRI-adaptation paradigm to show that the superior temporal sulcus (STS) contains separate neuronal populations tuned to different gaze directions. Participants were shown faces gazing to the left, directly ahead, and to the right. Adapting to a series of leftward-gaze faces caused participants to misidentify left gaze as direct, whereas adapting to rightward-gaze caused the opposite pattern. Similarly, the fMRI results showed that leftward adaptation produced a graded response in the right anterior STS, with left gaze showing the least activation, followed by direct gaze, and right gaze the most; the converse pattern was found following rightward gaze adaptation, with right gaze showing the least activation and left gaze the most. These findings provide the first human evidence of separable coding of different gaze directions in STS and are consistent with neurophysiological recording in non-primates.

◆ Spatial resolution of the visual system for discrimination of gender, identity, and expression from human faces

F W Smith, P G Schyns (Department of Psychology, University of Glasgow, Glasgow
G12 8QB, Scotland, UK; e-mail: fraser@psy.gla.ac.uk)

What is the spatial resolution of the visual system for objects such as faces? Thus, how far away can one be from a human face and still accurately categorise it? We explored this question using three face-recognition tasks—gender, identity, and expression—all based on the same stimulus set (ten actors, five male, five female, all posing the seven basic expressions). To examine spatial resolution, we manipulated viewing distance indirectly by altering the size of the images presented using the Laplacian pyramid technique (Burt and Adelson, 1983 *IEEE Transactions on Communications* 31 532–540). Our simulated viewing distances ranged, on a logarithmic scale, from about 3 m to 80 m. We derived threshold distances for each task and revealed the minimal spatial resolution under which each task could be comparably performed. We found that gender can be reliably discriminated from further distances than can identity, and both of these tasks from further distances than can expression. Furthermore, within the expressions task, we showed that expressions with large-scale diagnostic features (eg happy) can be discriminated better than expressions with fine-scale diagnostic features (eg sadness or anger).

◆ Category contingent face aftereffects suggest that distinct neural populations code faces of different races, ages, and species

A C Little, L M DeBruine¶, B C Jones§, C Waitt# (School of Biological Sciences, University
of Liverpool, Crown Street, Liverpool L69 7ZB, UK; ¶ School of Psychology, University of
St Andrews, St Mary's Quad, St Andrews KY16 9JU, Scotland, UK; § School of Psychology,
University of Aberdeen, William Guild Building, Aberdeen AB24 2UB, Scotland, UK;
School of Psychology, University of Stirling, Stirling FK9 4LA, Scotland, UK;
e-mail: a.c.little@liverpool.ac.uk)

Exposure to faces biases perceptions of subsequently viewed faces. Faces similar to those seen previously are judged more normal than they were prior to exposure. Category-contingent aftereffects have been shown for upright versus inverted faces and for male versus female faces, whereby adaptation to one category does not affect judgments of the other. Here we show category-contingent aftereffects following adaptation to eye spacing for European versus African faces (experiment 1), adult versus infant faces (experiment 2), and human versus monkey faces (experiment 3). Viewing faces of one category with increased eye spacing and faces of the other

category with decreased eye spacing simultaneously induced opposite aftereffects according to face category as assessed by normality judgments. Because aftereffects reflect changes in responses of neural populations that code faces, our findings suggest that distinct neural populations code faces of different races, ages, and species.

◆ **Limited-capacity face perception: evidence from priming**

M Bindemann, R Jenkins¶, A M Burton (Department of Psychology, University of Glasgow, Glasgow G12 8QB, Scotland, UK; ¶ MRC Cognition and Brain Sciences Unit, 15 Chaucer Road, Cambridge CB2 2EF, UK; e-mail: markus@psy.gla.ac.uk)

There is evidence that face processing is capacity-limited in distractor interference tasks and in tasks requiring overt recognition memory. We examined whether capacity limits for faces can be observed with a more sensitive measure of visual processing, by measuring repetition priming of flanker faces that were presented alongside a face or a non-face target. In experiment 1, we found identity priming for face flankers alongside non-face targets, but not alongside face targets. Experiment 2 showed perceptual priming, but not identity priming, of these flanker faces when they were presented alongside a face target. In experiment 3, identity priming of the flanker faces was eliminated during target face processing, and also during the processing of frontal views of cars, which resembled faces. By contrast, car targets which did not resemble faces did produce flanker face priming. Overall, these results imply that face processing is capacity-limited, such that only a single face can be identified at one time. Mere face-likeness of an attended target appears sufficient to trigger these capacity limits, although experiment 2 suggests that a second face in a display is nevertheless subject to superficial image processing.

◆ **Viewpoint dependence and independence in adaptation to facial identity**

C P Benton, S J Jennings, D J Chatting (Department of Experimental Psychology, University of Bristol, Bristol BS8 1TN, UK; e-mail: chris.benton@bristol.ac.uk)

We used face adaptation to study viewpoint dependence in face encoding. Adaptation is widely held to be functional and to target the assemblies of neurons encoding the adapting property. An adaptation paradigm therefore allows one to probe the underlying representation when the stimuli are well learnt at all viewpoints tested. We employed high definition 3-D head models provided by the Max Plank Institute for Biological Cybernetics in Tübingen. We rendered two head models to produce 2-D images at viewpoints ranging (in 15° steps) from -45° to 45° rightward rotation in depth. We then morphed between these two identities at each viewpoint to produce morph continua of 100 images at seven viewpoints. At each of these, we measured the strength of identity adaptation produced by the prolonged viewing of each of our two identities presented at the three-quarter rightward facing view. Our results show (i) robust adaptation across the range tested and (ii) a small but significant effect of viewpoint, with the largest effect of adaptation found when test and adaptor are presented at the same angle. Our findings support models in which identity is encoded by a mixture of viewpoint dependent and viewpoint independent mechanisms.

◆ **Attractive faces are not always average**

L M DeBruine, B C Jones¶, L Unger¶, A C Little§, D R Feinberg# (School of Psychology, University of St Andrews, St Mary's Quad, St Andrews, Fife KY16 9JU, Scotland, UK; ¶ University of Aberdeen, School of Psychology, William Guild Building, Aberdeen AB24 2UB, Scotland, UK; § School of Biological Sciences, University of Liverpool, Crown Street, Liverpool L69 7ZB, UK; # Department of Psychology, Harvard University, 33 Kirkland Street, 10th Floor, Cambridge, MA 02138, USA; e-mail: faceresearch@abdn.ac.uk)

Although some researchers have proposed that attractiveness is simply a function of averageness, others have found that caricaturing highly attractive faces (increasing the distance between average and 'attractive' shape) makes them mathematically less average but more attractive. Consistent with the first theory, prior research with visual adaptation paradigms has shown that perceptions of both normality and attractiveness of certain face types (eg faces with altered eye spacing) increase with exposure. Here we use a visual adaptation paradigm to test how exposure to highly attractive and unattractive faces affects perceptions of normality and attractiveness. Highly attractive faces were rated as both more attractive and less normal after adaptation to unattractive faces, but less attractive and more normal after exposure to attractive faces, opposing the theory that averageness and attractiveness are equivalent, and supporting the proposal that attractiveness continues to increase along a vector as it departs from the prototypical face towards attractive.

Friday

◆ **Facial feature integration in the human occipito-temporal cortex**

B Rossion, B Sorger¶, C Nameche, R Goebel¶ (Department of Cognition and Development, University of Louvain, 10 place du Cardinal Mercier, B 1348 Louvain-la-Neuve, Belgium;

¶Department of Cognitive Neuroscience, Maastricht University, NL 6200 MD Maastricht, The Netherlands; e-mail: bruno.rossion@psp.ucl.ac.be)

The recognition of a facial feature is dependent on the other features of the face stimulus, a phenomenon taken as evidence that faces are represented holistically. Here, we used fast event-related fMRI adaptation to test whether the regions responding preferentially to faces in the human visual cortex represent faces holistically. On each trial, subjects ($N = 11$) were shown a whole face stimulus followed either by a whole face or a single feature (the eyes). The eyes feature in the second stimulus could either be identical to the first stimulus, or different, leading to four conditions. Subjects were better at matching or discriminating the eyes when two whole faces were presented, replicating behavioural observations. In face-sensitive areas of the inferior occipital cortex, there was an adaptation when the same feature was presented in the two stimuli of a pair, whether the feature was presented in the same format (whole-to-whole) or not (whole-to-isolated). In contrast, and as predicted, there was a much larger adaptation in the whole-to-whole than in the whole-to-part condition in the middle fusiform gyrus. These results support the view that facial features are not represented independently, but rather integrated into a global representation in the middle fusiform gyrus.

[Supported by the Belgian National Foundation for Scientific Research.]

AUTHOR INDEX

Note: de X, van X, van den X, von X, and similar are all indexed under X

- Abutorabi A** 104
Acs F 184
Adachi T 211
Adams R 42
Adams W J 28, 35, 115
Adibi M 238
Adolphs R 138
Afraz S R 108, 219
Agostini T A 107, 180, 181, 227
Ahsan M 187
Ahumada A J 59
Aivar M P 64
Akthar F 3
Alais D 9, 127
Albert M 73
Albright T D 114
Alekchina M 223
Aleksandrov A Y 104
Alexeenko S V 170
Allan L G 113
Allen R 125
Allik J 138, 205, 217, 218
Allison R S 25
Altman J A 179
Alvarez R 82
Amano K 15
Amit D J 123, 124
Anderson G M 163
Anderson R S 193
Ando H 153
Anker S E 3
Apfalter W 143, 144
Aprile T 135
Arai S 109
Arakelian M A 230
Araki M 152
Ardid S 160
Arikawa K 139
Arndt P 103
Arnold D H 1, 15
Ashurova A 121
Aslin R N 115, 174
Aspell J E 201
Atkinson J 3a, 3b, 3c, 4, 5, 95
Atkinson N 176
Attar C H 43
Aust U 75, 142
Azadi R 108
Azarov K A 223
Aznar-Casanova J A 39, 206a, 206b
- Babenko V V** 161
Backus B T 113
Badakva A 224
Baddeley R 19, 227
Baeumer C C 133
Bagaeva T V 13, 103
Bagucka K 80
Bailes H J 116
Baker C I 8
Bakhshiev A V 17, 50, 55
Bal T 58
Balashevich L I 5
Baldassi S 72
Baldauf D 20
Baldo M V 137
Bales H J 168
Bao Y 61
Baptista C A 137
Barekatain M 134
Barlasov Ioffe A 44
Barraclough N 120
Barres L 198
Barrett B T 126
Barriouveau P A 213
Barth E 89, 110
Bastianelli A 216
Baud-Bovy G 151, 239
Bayerl P 43, 145
Beattie L L 22
Beaver J D 240
Becker C 215
Bekkering H 153, 188
Belin P 14
Benassi M 91, 94
Bennequin D 53
Bennett D M 34
Benson P 136
Benson V 84
Benton C P 241
Berg A V van den 9, 64, 145, 162
Berg R van den 188
Bergmann D 203
Bernáth L 215
Bertulis A 24, 42, 44c, 44d, 46
Bestelmeyer P E G 136, 208, 211
Bestmann S 234
Beutter B R 60
Bex P J 67, 90, 111
Bicego M 209
Bidet-Ildei C 220
- Bielevičius A** 44
Bimler D L 175, 185a, 185b, 185c, 187
Bindemann M 211, 241
Birtles D B 3, 4
Bjoertomt O 234
Black R H 27
Blajenkova O 226
Blankenburg F 234
Bleumers L 77
Blochina A S 17, 55
Blouin J 179
Blythe H I 236
Boeddeker N 165
Böhme M 110
Boidot M 141
Boiko E V 129, 230, 231
Boloix E 17
Bolzani R 91, 94
Bompas A 88
Bondar I V 109, 121
Bondarko V M 158, 173
Bone I 231, 235
Bonnardel V 185, 187
Bordier C 157
Borji A 105
Borra T 28
Bosten J M 193
Bouamama S 81
Bouchard M 47
Bouet R 195
Boukhtiarov I V 223
Bourne V J 85
Bours R J E 218
Bowmaker J K 116, 167
Boxtel J J A van 32
Boy F 152
Boychuk I M 23, 130, 132
Bozhinskaya M A 161
Braddick O J 3a, 3b, 3c, 4, 5, 95, 238
Brand A 135
Brascamp J W 9, 162
Braun C 220
Braun J 156
Brecher K 30
Brelstaff G J 37, 209, 226
Bremmer F 11
Brémond-Gignac D 229
Brenner E 21, 22, 32, 64, 127, 178
Bresciani J-P 102, 179
Bressanelli D 43, 182

- Brettel H 36, 191
 Bridge H 29
 Bridgeman B 108
 Briscoe A D 142
 Briscoe J 65
 Brodo L 209
 Brouwer A-M 65, 86
 Bruno A 1
 Brzhesky V V 94
 Bucci M P 229
 Buckingham G 151
 Budiene B 197
 Budnik U 43
 Buetti S 151
 Bukhtiyarov I V 188
 Bulatov A 24, 42, 44c, 44d, 46
 Bulatova N 44
 Bülthoff H H 33, 35, 128, 179, 210
 Bülthoff I 204
 Bunyakov V A 16, 48
 Burgess A M 83
 Burmester A 157
 Burr D C 2, 7
 Burton A M 241
 Burton M 194, 210
 Bushueva N N 130
 Busse L 220
 Butler S H 97, 231, 235
 Butterworth B 155
 Caldara R 211
 Calder A J 240
 Cameron J I 179
 Campana G 163
 Capern S 53
 Carbon C-C 135, 199, 200, 210
 Carey D P 151, 231
 Carleton K L 116
 Carrasco M 7, 161
 Carson R G 149
 Carvalho L 167
 Casanova C 110
 Casco C 71, 74, 163, 239
 Casile A 153
 Cass J 127
 Castet E 19
 Casti A R R 21, 59
 Cavanagh P 171
 Chambers D P 179
 Chanderli K 17
 Chang Y-H 206
 Chatting D J 241
 Chaumet G 47
 Chaura A G 130
 Chauvin A 56
 Chavane F 54
 Chemla S 53, 54
 Chen C-C 78
 Chen D-Y 78
 Chen H C 78
 Chen J-H 78
 Chen L 61
 Chen X 237
 Chen Y-C 80
 Cherepennikova T Y 96, 133
 Chernookova V A 232
 Chernush V F 231
 Chessa F 226
 Chichua A 190
 Chichua G 190, 214
 Chihman V N 158
 Chiller-Glaus S 212
 Chirimuuta M 7
 Chkonia E 135
 Cho K 209
 Chou W-L 78
 Choubey B 25, 51
 Chuang L 33, 69, 99
 Chueva I V 41, 76
 Chung M 209
 Cicchini G M 87, 101
 Cioni G 72
 Clara E 183
 Clarke A H 223
 Cleeremans A 239
 Clifford A 192
 Coello Y 148, 149, 152
 Colby C L 11
 Collée C 98
 Collett T S 139
 Collin S P 116, 168
 Collins T 84
 Colomb M 56, 136
 Colombo E M 191, 196, 213
 Colonius H 103
 Coltheart M 133
 Cone R E 177
 Cong K-D 62
 Conrad V 101
 Conte M M 121
 Conway C A 210, 211
 Cornelissen F W 54, 129, 153, 188, 214, 215
 Cornwall M C 117
 Corrado G S 169
 Correani A 180
 Costa M F 185
 Coull J T 1
 Couronné T 83
 Courtney J R 218
 Cowan F M 3
 Cowie D A 95
 Cowing J A 167
 Craft E 122
 Creanga D-E 17, 52, 141
 Crippa J A S 137
 Cristino F 19
 Cronin T W 167
 Crouch R K 117
 Crouzet S 128
 Crundall D 8
 Cunningham L P 90
 Cunnington R 20, 235
 Curthoys I S 83
 Daini R 144
 Dam L C J van 25
 Dammeier F 102
 Danilova M V 67, 173, 192
 d'Arch-Smith C 179
 Date M 30, 31
 Davies I R 39
 Davies I R L 74, 192, 194
 Davies W L 116, 167
 Debay D 58
 DeBruine L M 208, 210, 211, 240, 241
 De Graef P 38, 77
 Degtyarenko T V 130
 Dejonckheere P J N 92
 Delahunt P B 192
 Delord S 47
 Demchenko T V 192
 Demeyer M 39
 Deouell L Y 201
 Deplancke A 149
 Deruaz A 81
 Deshkovich A 129, 130
 de'Sperati C 87, 217, 239
 Destexhe A 58
 Deubel H 12, 20, 75
 Devinck F 192
 Devisme C 32
 Dewhurst R C 8
 Dhruv N T 108
 DiCarlo J J 8
 Di Filippo G 174
 Di Russo F 135
 Dischler E 186
 Ditye T 199
 Dojat M 195
 Dolan R J 240
 Donk M 233
 Donner K K 118
 Doré-Mazars K 84
 Dorffner G 18
 Dorr M 110
 Dotsenko V I 188

-
- Doubrovski V E 49
 Doucet M 205
 Dragoi V 13
 Drawing K 237
 Driver J 234
 Drivonikou G V 74
 Drobe B 32
 Droulez J 32, 53
 Drozhenko V S 130
 Dryja T P 129
 Duangudom V 66
 Dubois M 83
 Dudai Y 113
 Dudkin K N 41, 76
 Duffie F 185, 187
 Duijnhouwer J 145
 Dukelow S P 64
 Duncan G 231, 235
 Dunn A K 42, 178, 207
 Dupuis-Roy N 205
 Durant S 220
 Dutton G N 34
 Dyer M A 168
 Dzhakupov S 36
 Eagleman D M 2
 Eckstein M P 60
 Edwards A D 3
 Ee R van 9, 10, 25, 26, 29, 30, 32, 53, 162
 Efimova E L 134
 Eger E 240
 Eggert T 8, 147
 Ehmer A 23
 Ehrenstein W H 37
 Einevoll G T 59
 Eisenbarth W 62
 Elliott M A 92
 Elze T 52
 Engbert R 230a, 230b
 Erkelens C J 10, 26, 32
 Ernst M O 88, 101, 115
 Eron J N 224
 Escobar M-J 55
 Espiner C 85
 Essid S 73
 Estaún Ferrer S Sr 101
 Etchells P J 64
 Ezzati A 219, 238
 Fabre-Thorpe M 76, 141
 Facoetti A 91
 Fago de Mattiello M L 82
 Fahle M 8, 79, 177
 Fahretdinova D A 100
 Fairhall S L 225
 Falkenberg H K 90
 Fan Z 145
 Faye P 83
 Fedorova E S 96
 Feinberg D R 241
 Feitosa-Santana C 185
 Fendrich R 203
 Fernandez G 170
 Field D J 226
 Field D T 46, 63, 65
 Filho A S 137
 Findlay J M 84, 236
 Finlay B L 168
 Finzi A 91
 Fiser J 115, 174
 Fize D 76, 141
 Flanagan P 9
 Fleishman L J 168
 Florer F 98
 Flückiger M 17
 Fokin V A 18, 72, 125, 129, 130
 Folta K 66
 Fomins S 87, 136
 Fontaine R 16, 98
 Fontes A I 77, 106
 Fontes S 77, 106
 Ford G 222
 Foreman N P 36, 125
 Formankiewicz M A 213
 Foulsham T 236
 Francis G 54, 66
 Franklin A 74, 192, 194
 Franz V H 86, 148
 Freeman E D 221, 234
 Freitas M C S 137
 Fritz G 18, 48b, 48c
 Fu L 61
 Fujita K 217
 Fukusima S S 206a, 206b
 Funke K 58
 Gaillard J-P 110
 Galinovskaya N V 95
 Galmonte A C G 107, 180, 181, 227
 Ganem R 229
 García-Ogueta M I 157
 Garusev A V 49
 Garway-Heath D F 193
 Gauch A 101
 Gauchou H L 128
 Gauthier G M 179
 Gavault E 159
 Gegenfurtner K R 110, 194, 235
 Geier J 215
 Georg K 229
 Georgeson M A 227
 Gepshtein S 16, 80, 100
 Ghim H 209
 Ghisovan N 13
 Giaschi D E 171
 Gibbons W 81
 Gibbs P 9
 Giese M A 153
 Gilchrist A 181
 Gilchrist I D 83, 158, 231, 235
 Gillam B J 68
 Gillebert C R 35
 Gillet P-C 47
 Gintautas D 229
 Giora E 71, 74
 Giordano A M 7
 Giovagnoli S 91, 94
 Graudeau C 91, 98
 Giraudet G 32
 Glezer V D 68
 Gobbetti E 37
 Goebbels K 141
 Goebel R 242
 Goldbach M 217
 Goldschmidt M 81
 Golzar A 219
 Gomes B D 175
 Goonetilleke S C 83
 Goossens H H L M 64
 Gordon G E 34
 Gosselin F 138, 205
 Gotoh Y 31
 Gougoux F 14
 Goujon A 46
 Goutcher R 25
 Govardovskii V I 119
 Graf E W 28, 115
 Graham D J 226
 Grainger J 81
 Granger-Donetti B 172
 Granstrem M P 103
 Granzier J J M 21, 22
 Grave D D J de 86
 Grayson L E 65
 Greenlee M W 103, 184
 Gregory R 226
 Griffin L D 48, 57a, 57b
 Grimoldi G 239
 Grosjean M 33, 156
 Grosso E 209
 Grosso R A 151, 216
 Grove P M 202
 Grueschow M 111
 Gschwind M 36
 Guardini P 74

- Guérin-Dugué A 83, 100
 Guerraz M 179
 Guillaud E 179
 Guillemot J-P 14
 Gummel K K 91, 94
 Gundorova R A 132
 Gutauskas A-J 42
 Guyader N 56
 Guziy J A 94
 Haarmeier T 160
 Haggard P 85a, 85c
 Hallak J E C 137
 Hammer R 75
 Hammond B R Jr 189
 Han J 198, 199
 Han S 63
 Hancock P J B 209
 Hannus A 153, 188
 Hansen T 194
 Harauzov A K 18, 72a, 72b,
 125, 129, 230
 Hardy J 192
 Harmening W M 141
 Haroush K 201
 Harper L 185, 187
 Harrar M 191
 Harris J M 10, 38
 Harris J P 46, 145
 Harrison N R 201
 Hart N S 116, 168
 Harvey B M 238
 Harvey M 97, 231, 235
 Haslwanter T 223
 Hatada T 30
 Hatada Y 202
 Hauert C-A 234
 Havanur S G 145
 Havard C 210
 Hay J L 161
 Hayashi T 148
 Haynes J-D 234
 Heard P F 42
 Heekeren H R 169
 Heering A de 98
 Heggelund P 58
 Heinke D 163
 Heinze H-J 111, 203
 Hekking B 162
 Hellmann A 39
 Helm P A van der 28
 Hemmi J M 165
 Hempel de Ibarra N 138,
 139, 166
 Hennig J 43
 Henson R N A 240
 Henze M J 142
 Hérault J 56
 Hernaha Y O 134
 Hertz T 75
 Herzog M H 40, 41, 45a, 45c,
 66, 67, 135, 174
 Hesse C 86, 148
 Hesse G 227
 Hetley R S 10
 Heydt R von der 122
 Hibbard P B 25, 27, 178
 Hill H C H 137
 Ho C S 171
 Ho Y X 115
 Hochstein S 7, 44, 75, 123,
 124, 201
 Hofbauer M 147
 Hofer F 212
 Hofsten C von 93
 Hogervorst M A 51
 Hogg A L 209
 Holcombe A O 65
 Holmes A 192
 Holschneider M 230
 Hooze I T C 28
 Hoormann W J 27
 Houtkamp R 89
 Hsu L-C 159
 Hubbard T L 218
 Huber J W 39
 Huber L 75, 142, 143, 144
 Huckauf A 146, 173
 Hudák M 215
 Hudson M 154, 207
 Humphreys G W 163
 Hunt D M 116b, 116c, 167
 Hurlbert A C 23, 90, 201,
 225
 Husbands P 139
 Hutchinson C V 238
 Hutchinson S J 180
 Hwang E Y 222
 Hyönä J 125
 Hyvarinen A 89
 Idesawa M 26, 183, 237
 Iftime A M 133
 Igliozi R 72
 Ignashchenkova A 160
 Ignat E M 52
 Ikaunieks G 129, 136
 Ikeda T 106
 Ildei C 95
 Imura T 37
 Inoue K 219
 Inshakova O B 94
 Intskirveli I 214
 Inui T 148
 Inukai T 155
 Isaev E V 17, 55
 Ishai A 225
 Ishi H 211
 Ishibashi K 154
 Ishigure Y 30
 Ishikawa K 30
 Israel A 159
 Issolio L A 213
 Ivanov A N 132
 Ivanov I 149
 Ivanov R S 109
 Ivanov S 105a, 105c
 Ivanova V Y 104
 Izmailov C A 176
 Jacomuzzi A 239
 Jainta S 27
 Janelidze D 214
 Janković D 90
 Janssen P 2
 Jayasuriya C C 73
 Jazayeri M 18
 Jean A 20
 Jellema T 120, 154, 207
 Jenkins R 240, 241
 Jennings S J 241
 Jingling L 71
 Johnson S 109
 Johnston A 1, 15, 137, 155
 Jones B C 208, 210, 211, 240,
 241
 Jordan G 176
 Joubert O 76
 Juneja V 111
 Jung W H 198, 199
 Jurcoane A 25
 Kalviainen H 49
 Kamarainen J 49
 Kamiya S 109
 Kanazawa S 4a, 4b, 92, 93
 Kanwisher N G 8
 Kaplan E 12, 21, 59
 Kapoula Z 88, 200, 229
 Karitans V 87, 136
 Kaspranskaya G R 86, 223
 Kaspransky R R 86, 223
 Katzner S 220
 Kaufmann J M 203
 Kawabe T 202
 Kawahara T 36, 152
 Kawamura K 123a, 123c
 Kayaert G 154
 Kayahara T 204
 Kazaryan A A 230
 Keeble D R T 10

-
- Kelber A 142, 166
Kerzel D 82, 84, 85, 101,
104, 151
Kezeli A 40, 63, 96, 135, 143,
190, 214
Khomenko M N 188
Khomeriki M 143
Khon N 36
Kikuchi T 154, 219
Kim A 36
King-Casas 170
Kinoshita M 139, 166
Kiorpes L 66
Kiper D 76
Kirchner H 128
Kirenskaya A V 224
Kirkland J 185
Kita S 154
Kitaoka A 4
Kitazaki M 150
Kleiner M 212
Kleiser R 234
Kliegl R 230
Klucharev V 170
Knapen T 30, 32
Knappmeyer B 212
Knez I 131
Knill D C 65
Knoblauch K 157, 195
Koch A 207
Koch C 12
Kochukhova O 91
Koechy N 111
Koene A R 202, 233
Koesling H 146
Kogo N 40
Kojima H 40
Kolbanov V V 136
Kolikoff M 189
Kolodziejczyk I 61
Kolomiets V A 134
Komischke B 138
Koning A 40
Konishev V A 98, 99
Konkle T 156
Kono M 117
Kononov V M 134, 171
Kooijman A C 129
Korablev D V 198
Körner C 83
Kornilova L N 188, 222, 223
Kornprobst P 53, 54, 55, 67
Korsakov A M 17, 50a, 50b,
55
Koshits I N 5
Koskin S A 129, 230, 231
Koteles K 34
Kotliar K 5
Kouchi S 211
Kozhevnikov M 226
Kozhina G V 222
Kozlovskaya I 223, 224
Kozyrev V 160
Krägeloh-Mann I 220
Krasilnikov N N 36, 60, 125,
129
Krasilnikova O I 36, 60
Krasnoperova N A 96, 133
Krauskopf J 175
Kreegipuu K 138, 205, 218
Kremláček J 217
Kristjánsson A 114, 164
Krnavek J M 222
Kroes M 218
Kropotov J D 124
Krumina G 136
Kubovy M 80
Kuldkepp N 217, 218
Kulikov G A 104
Kunitskij A A 103
Kupenova P N 189
Kuribayashi H 30
Kurki I 89
Kuzhda I N 6
Labhart T 142
Labusch K 89
Lacis I 80, 87
Lafon P 91, 98
Lago M 185
Lak A 105
Lall A B 140
Laloyaux C 239
Lamalle L 195
Lamb T D 117
Lancelin D 20
Landy M S 115
Langendörfer M 118
Langley K 67, 111
Lankheet M J M 218
Lappe M 84, 229, 234
Lasas V 44
Lasenby J 179
Lassonde M 14, 205
Latto R M 27
Laurinen P I 45, 89
Lauritzen J S 55, 95
Lauwereyns J 124
Lawson R 27
Lebedev D S 21, 195
Leboulle G 138
Leder H 199
Ledgeway T 238
Lee B B 175
Lee C-H 179
Leeuwen C van 80, 100
Lehky S R 111
Leigh R J 222
Le Masson G 58
Lengyel M 115
Lennie P 108
Lensu L 49
Leonards U 64, 158, 180,
234, 237
Leonov Y P 186
Leopold D 121
Lepore F 14, 205
Lestocart L J 200
Levashov O V 86, 94, 106
Levi D M 126
Li J Q 110
Li Y 182
Liebe S 88, 141
Lier R van 47, 92, 107, 150,
162
Likova L T 71
Lillholm M 48
Lin S-Y 78
Ling Y 23, 90
Little A C 208, 211, 240, 241
Little J A 55, 95
Liu C H 154, 212
Liversedge S P 84
Lochte A 160
Loffler G 34, 99
Loginovich Y 24
Logothetis N K 88, 121,
141, 207
Logvinenko A D 22, 180
Loidolt M 142
Lomashvili N 143
Lommertzen J 150
Lopez-Moliner J 63
Lorincz E N 81
Lotto R B 140
Loureiro S R 137
Louw S 127
Love A 156
Lovell P G 106, 181, 227
Lu T 180
Lucassen M P 51, 214, 215
Ludmer K 113
Ludwig C J H 60, 231, 235
Lukauskienė R 196, 197a,
197b
Lussanet M H E de 234
Lutsiv V R 50
Luxat D 160
Lyakhovetskii V 105

-
- Macar F** 1
McBride J 158
McCann J J 22, 51, 190
McDermott K 60
McDonald J S 101
McGeorge P 125
McGlone F 235
Machatschke I H 143
McIlhagga W 59
McIntyre A H 209
MacKeen M 62
McKee S P 173
McKeefry D 194
McLachlan J M 159
MacLeod M-J 232
McQuaid J R 177
Macramalla S 108
McSorley E 85
Maeda T 153
Maertens M 121
Magnussen C M 99
Maiche A 158
Majaj N J 68, 108
Makarov F N 5, 41, 97, 123a, 123c
Malania M 40, 174
Maloney L T 115
Malysheva P 105
Mamassian P 228
Manahilov V 15
Mante V 12
Marendaz C 56, 83
Marino B F M 147
Markall H 212
Markova L A 123
Marković S 198
Marlow P 68
Marshak D W 21, 195
Marshall J 168
Martelli M 174
Martin A 219
Martin J N 64
Martinetz T 89, 110
Marzouki Y 81
Masame K 211
Mascalzoni E 140
Massironi M 43
Masson G 67
Massot C 56

Mate J 101
Mather G 69
Mattingley J B 20, 235
Matveev V I 6
Maurizot M 110
Mausfeld R 213

Ma-Wyatt A 150
Maximov P V 195
Meary D 95
Medvedev L N 43, 96
Melcher D 11
Meng X 182
Menon R S 64
Menshikova G 183
Menzel R 138
Merkulieva N S 97
Mermoud C 81
Meso A I 218
Meulenbroek R G J 150
Meyer G F 201
Mezentsev A Y 79
Mezey L E 83
Michels L 234
Mickiene L 46
Miguel S 39
Mihaylov P O 15
Mikhailova E S 98, 99
Milders M 73, 161, 193
Milleret C M-T 171
Miller N V 224
Minini L 149
Miroshnikov M M 14
Mishiro M 150
Mitova L L 189
Mitsui K 199
Miura K 202
Miyazawa K 197
Mogi K 160, 183, 200
Moiseeva V V 222
Mollon J D 1, 67, 127, 176, 193, 213, 215
Molotchnikoff S 13, 47
Monot A 32
Montagnini A 19
Mon-Williams M A 132
Morange P 56
Morgan M J 15, 68, 102, 175
Mori T 155b, 155c
Morrone M C 2, 7
Morvan C 228
Mota A M 137
Motes M A 226
Moutsiana C 46
Movshon J A 12, 18
Muckli L 25
Muir K 231, 235
Mukhitdinova T 36
Muller C M P 32
Munhall K 120
Muniz J A P C 168
Muratori F 72
Muravyova S 130

Murd C 205
Murray R F 14
Mustard H 207

Najafian A 27, 196, 216
Nakajima M 204
Nakato E 93
Nakauchi S 197
Nakayama D 36
Nameche C 242
Nandy A S 172
Napalkov D A 189
Narasimhan S 126
Nardini M 3b, 3c
Nasr S 134
Nasrallah A J 57
Naumov I A 223
Nefs H T 38
Nemri A 13
Neumann H 145
Newell F N 184, 204
Newsome W T 169
Niebur E 122
Niedeggen M 161
Nielsen K J 207
Nieuwenstein M 156
Niggebrügge C 138
Nijs M M 29
Nikitin N I 179
Nikitina E 208
Nikitina O 82
Nikolaev A R 80
Nikonov S S 118
Nilsson D-E 167
Ninio J 70
Nishida S 1, 195
Niven J E 165
Noda M 93
Nodoust B 104
Noel Y 110
Noesselt T 203
Noest A J 9, 29, 53, 162
Noppeney U 35
Noudoost B 27
Novototski-Vlasov V Y 224
Nucci M Sr 79
Nuding U 62
Nurminen L O 45

O'Brien J M D 131, 137
Ochiai F 208
Oda H 197
Odesawa M 237
O'Donell B M 191, 196
Ögmen H 67
Ognivov V V 97
Ohmi M 147

-
- Ohtsuka S 152
 Oiwa N N 185
 Oksama L 125
 Oliiva A 100
 Olk B 161
 Olkkonen M 194
 Olson J 232
 Olzak L A 89
 Omlor L 153
 Onouchi T 197
 Ons B 33, 35, 154
 Op de Beeck H P 8, 33, 35
 Oram M W 120
 Orbán G 115
 Orban G A 34
 O'Regan J K 128
 Orliaguet J-P 95, 152
 Orlov O Y 74, 138
 Orlov T 124
 Osaka M 106
 Osaka N 106
 O'Shea R P 9
 Osorio D 169
 Osório F L 137
 Otazu X 56
 Otsuka Y 92
 Otto N 100
 Otto T U 40, 41, 67
 Ozolinsh M 87, 129, 136
P
 Pacey I 10
 Paeglis R 80, 87
 Page K B 226
 Pagnotta G 144
 Paladini C 230
 Palermo R 133
 Paletta L 18, 48b, 48c
 Palix J 234
 Palluel-Germain R 152
 Pallus A 168
 Papatthomas T V 224
 Pamei G V 176, 185
 Park S 198, 199, 209
 Parker A 9
 Parker A J 29
 Parkkinen J 87, 136
 Parkosadze K 40, 190, 214
 Parovel G 44, 239
 Párraga C A 227
 Parry J W L 116, 167
 Pastukhov A 156
 Patel J 27
 Pavani F 228
 Pavlova M 74, 119, 220
 Pearson P M 159
 Pechenkova E V 102
 Pei F 72
 Pelah A 179
 Peled A 203
 Pelizzone M 17
 Pelli D G 68, 172, 173
 Pelphrey K A 119
 Pepperell R 225
 Perez Fornos A A 17
 Perrett D I 120
 Perrinet L 67
 Pescio S 82
 Pestilli F 161
 Peterson M A 114
 Peterzell D H 177
 Petrov Y 173
 Philippides A 139
 Phillips L H 136
 Piché M 14
 Pikulins A 87
 Pilz K S 69, 210
 Pin A 107
 Pinna B 43, 73, 200
 Pires A 101
 Pirtskhalaishvili M 190
 Pizlo Z 182
 Plomp G 100
 Plumb M 132
 Pöder E 187
 Podniece A 87
 Podugolnikova T A 171
 Podvigin N F 13, 100, 103a, 103b
 Podvigina D N 13, 100, 103a, 103b
 Poggel D A 62
 Pollirer M 143
 Pollmann S 121
 Polosin L L 186
 Poncet S 229
 Ponomarchuk V S 132
 Popov K E 222
 Popova E B 189
 Popple A V 173
 Porter M L 167
 Portolan N 110
 Potapov A S 78, 105
 Pott J W R 129
 Potter I C 116
 Prado J 157
 Premereur E 2
 Procida G 72
 Pronin S V 18, 52, 72a, 72b, 79, 125
 Ptitto M 110
 Puca R M 107
 Pugh E N Jr 117, 118
 Pye R E 94
R
 Raabe M 184
 Radonjić A 181, 198
 Rainer G 88, 141, 207
 Ramachandran V S 177
 Ratmanova P 189
 Redmond T 193
 Rees G 234
 Reeves G 235
 Reeves I 231
 Regolin L 140, 183
 Reilly R G 146
 Renner A 158
 Rentschler I 36
 Reschke M F 222
 Reynaud A 54
 Rezaii N 104
 Riabinina O 139
 Rich A N 235
 Richard G 141
 Richmond B J 122
 Richter H O 131
 Riddell P M 81, 94
 Ridgway N C 193
 Rieger J W 111
 Riek S 149
 Righi G 107, 181
 Rinkenauer G 33, 107, 156
 Ripoll T 73, 159
 Rizzi A 51
 Robertson D 203
 Rochel O 53
 Rock P B 227
 Rodrigues A R 175
 Roeber U 26
 Roelfsema P R 89
 Roerdink J B T M 188
 Roether C L 153
 Rogers L J 183
 Rogovanov D I 231
 Roinishvili M 135, 214
 Rolfs M 237
 Rome E 18
 Rosander K 93
 Rossion B 242
 Rossit S 97
 Roth S 76
 Rothwell J C 85
 Rousselet G A 76
 Roy J 110
 Rozhentsov V V 232
 Rozhkova G I 96, 133, 171, 232
 Rubin N 113
 Rudoy I 129
 Ruff C C 234
 Rumyantseva R A 86

-
- Ruparelia K 137
 Rushton S K 70, 144
 Rust N C 12
 Rutherford M A 3
 Rutschmann R M 184
 Saarela T P 45
 Sadovnikov A 49
 Saeidian B 216
 Safran A B 17, 81
 Sahraie A 73, 151, 161, 193, 231, 232
 Saibene F 144
 Saïda S 152
 Saiki J 126
 St Clair D 136
 Saito C A 175
 Sajjadi M 212
 Sakaguchi Y 77
 Sakata K 190
 Sakurai K 202
 Saltykov K A 109
 Salvano-Pardieu V 16, 98
 Samuel F 104
 Sanayei M 27, 134, 187, 196, 212
 Sarkheil P 35
 Sato T 109
 Saunders K J 95
 Saygin A P 120
 Sayim B 45
 Scarfe P 27, 178
 Schaefer E G 159
 Schalk F 111
 Scharff L F V 59
 Schellenberg M 159
 Schill K 62
 Schlack A 114
 Schmalzl L 133
 Schmid J C M von 162
 Schneider A 211
 Schneider W X 12, 75
 Schnider A 81
 Schofield A J 227, 238
 Schor C M 31
 Schouten B 205
 Schreiber K M 31
 Schröger E 26
 Schultz J 99, 101, 128
 Schütze H 122
 Schwaninger A 212
 Schwarz D R 49
 Schwarzbach J V 169
 Schweinberger S R 208
 Schyns P G 138, 205, 240
 Scocchia L 81, 151
 Scott-Samuel N E 64, 180
 Seebacher D 142
 Seehausen O 116
 Segebarth C 195
 Seiffert A E 70
 Seitz R J 234
 Selchenkova T 72a, 72b
 Séra L 215
 Serdyuchenko V I 6
 Sereno A B 111
 Servos P 120
 Setti A 184
 Sevostyanov A 18, 72
 Shahsavarzadeh T 196
 Shamshinova A M 230
 Shanagher L M 92
 Shandurina A N 131
 Sharafutdinova R H 43
 Sharikadze M 62, 63, 96
 Sharpe L T 118, 176
 Shelepin Y E 6, 14, 18, 52, 60, 72a, 72b, 79, 125, 129b, 129c, 130, 230
 Shepeleva I P 139
 Shepherd A J 130, 216
 Shevelev I A 98, 109, 122
 Shi Z 217
 Shibui S 207
 Shichida Y 116
 Shiina K 199
 Shimomura T 155
 Shin S 198, 199
 Shinomori K 197
 Shirai N 4, 37
 Shkorbatova P Y 170
 Shneur E 7
 Shoshina I I 43, 96
 Shulgovsky V V 189, 222
 Shumaker S 60
 Shumikhina S 13, 47
 Shvetsova N E 132
 Shyi G 78
 Sidamonidze Kh 143
 Siebeck U E 143
 Siegel S 113
 Siewert U 89
 Sigala R 207
 Sikl R 38
 Silva K C 137
 Silva Filho M da 168, 175
 Silveira L C L 168, 175
 Simecek M 38
 Simoncelli E P 12
 Simoneau M 179
 Simpson W A 15
 Sinico M 44, 239
 Sireteanu R 25, 133, 171
 Sison-Mangus M P 142
 Slaghuis W L 109
 Slavutskaya A V 98, 99
 Slavutskaya M V 222
 Sligte I G 158
 Slobodyanik S B 132
 Smeets J B J 21, 22, 32, 64, 127, 178
 Smetanin B 222
 Smidts A 170
 Smith A T 69
 Smith F W 240
 Smith L 95
 Smithson H E 176
 Smolnikov B 5
 Sobolev A 127
 Sobolev A F 129, 230
 Sokol S H 108
 Sokolov A 74, 220
 Sokolov E N 186
 Solomon J A 15
 Solovieva A D 188
 Somers J T 222
 Sommer M A 10
 Sommerhalder J 17
 Somov E E 6
 Soranzo A 180, 227
 Sorger B 242
 Sorkin A 203
 Sousa J P M de 137
 Souto D 85
 Souza G S 175
 Spady T 116
 Spang K 8, 79, 177
 Speck O 43
 Spencer J V 131, 137
 Sperling M 235, 237
 Sperling G 20
 Spezio M L 138
 Spillmann L 192
 Spinelli D 135, 174
 Spitoni G 135
 Srinivasan N 145
 Stanislovaitienė D 197
 Staude G 62
 Stavenga D G 166
 Stavros K A 66
 Steinman R M 182
 Stepanov D N 50
 Sterzer P 221
 Steurer M M 142, 144
 Stine W W 10
 Stockman A 118, 176
 Strakhov V V 6
 Strang N 15
 Strasburger H 62

-
- Stringer N 39
 Stringham J 189
 Stritzke M 150
 Struiksma M 30
 Stuart G 9
 Stucchi N 81, 147, 151
 Sugrue L P 169
 Sukemiya H 202
 Sumner P 236
 Sun H 175
 Sunaga S 191
 Supèr H 39
 Suyama S 30, 31
 Suzuki N 208
 Svede A 82
 Svetlova O 5
 Szelag E 61
 Szymaszek A 61
Tabin G 41
 Tailby C 108
 Takada H 30, 31
 Takahashi M 153
 Takahashi S 214
 Takeda T 15
 Takehara T 208
 Takeichi M 217
 Taliercio A 16
 Tallon-Baudry C 128
 Tamm M 138
 Tamori Y 200
 Tanaka H 191, 217
 Tancredi R 72
 Tang D-L 159
 Tanner T G 41
 Tanskanen T 201
 Tartaglia E 41
 Tatler B W 85, 136
 Tatsuno Y 148
 Taya F 160
 Temnikova V V 188, 223
 Terletsckaja O Y 132
 Thier P 160
 Thomas R D 89
 Thompson P 42, 178
 Thornton I M 33, 70, 210, 239
 Thorpe S J 128
 Tibber M S 130
 Tiggelaar E L 215
 Tillman K A 173
 Tillmann C 220
 Timofeev I 12
 Tjan B S 172
 To M 106, 181
 Todorović D 181
 Tokareva V S 97, 232
 Tolhurst D J 106, 181, 227
 Tolmacheva M 190
 Tomilovskaya E 224
 Tomonaga M 37
 Toporova S N 170
 Torro-Alves N 206a, 206b
 Tosković O 40
 Treder M S 28
 Tresilian J R 149
 Treue S 160, 220
 Treutwein B 62
 Trevethan C T 231, 232
 Trezise A E O 116
 Trifonov M I 53
 Tripathy S P 126b, 126c
 Troje N F 107, 144
 Trommershäuser J 16, 150
 Troscianko T 106, 181, 227
 Trufanov E G 230
 Trufanov G A 18, 125
 Trunkenbrod H A 230
 Trutty-Coohill P 225
 Trzesniak C 137
 Tsapenko I V 132, 232
 Tseng C-H 20
 Tsermentseli S 131
 Tsinoglou M 109
 Tsirlin-Zaharescu I 25
 Tyler C W 71
 Tzvetanov T 66
Uehira K 24
 Ulmann B 82
 Underwood G 236
 Unger L 241
 Urevich E I 48
 Usova N N 95
 Uusberg A 217
Vaissertreiguer A S 104
 Vakhrameeva O A 79
 Valberg A 186
 Vallortigara G 183
 Valsecchi M 87
 Van Belle G G 38
 Vangeneugden J 34
 Vanni M 110
 Vanrell M 56
 Vasiljeva N N 29
 Vassilev A 193
 Velichkovsky B M 19
 Ventura D F 185
 Verbeke E 154
 Verfaillie K 38, 77, 205
 Vergeer M L T 47, 162
 Verigo E N 232
 Verschure P F M J 76
 Verstijnen I M 162
 Verstraten F A J 28
 Vesper S 26
 Vetter P 155
 Viazovsky I A 6
 Vicari S 91
 Victor J D 121
 Vidal F 1
 Vidal J R 128
 Vidotto G 216
 Viénot F 191
 Viera J 161
 Viéville T 53, 54, 55, 67
 Vilis T 64
 Viliunas V 196, 197a, 197b
 Villarino A 77, 106
 Villeneuve M 110
 Visser T 20
 Vitanova L A 189, 190
 Vitu F 20, 237
 Vizireanu D N 34, 49
 Vladusich T 54, 214, 215
 Vliegen K 154
 Vogels R 34
 Volkov V V 6, 177
 Vorobyev M 166, 168a, 168b
 Vorobyov O 188
 Voss P 14
 Vrins S 92, 107
 Vul E 156
 Vuong Q C 33, 35, 69, 99, 210
Wagemans J 33, 35, 39, 40, 77, 79, 154
 Wagge J R 89
 Wagner H 141
 Wagner M 37
 Waitt C 240
 Walker R 85
 Wallis G M 114, 157, 229
 Wang T Z 24
 Wang X 61
 Wann J P 63, 65, 146
 Ward J 212
 Warren P A 70, 144
 Warshafsky J 3
 Watanabe H 208
 Watanabe J 1, 153, 195
 Watson A B 59
 Watt S J 178
 Wattam-Bell J 3, 4, 5, 149
 Webster M A 60
 Webster S M 60
 Wede J 54
 Weerda R 103
 Weinshall D 75, 203
 Weisbecker A 148

-
- Weiskrantz L 231, 232
 Weitenberg A I M 51
 Welling L L M 208, 211
 Wendt G 213
 Werner A M C 23, 149, 219
 Werner J S 192
 Westheimer G 174
 Wexler M 184, 228
 Wezel R J A van 29, 145
 Whatham A R 81
 Wicklein M 140, 165
 Wilcox L M 25
 Wilkie R M 65, 146
 Wilkie S E 167
 Williams J H G 132
 Williams M A 20, 156, 235
 Wilson A D 132
 Wink B 16
 Winston J 240
 Wischhusen S 8, 177
 Wismeijer D A 26
 Wit T C J de 92, 107
 Wohrer A 55, 67
 Wolf W 62
 Wolfart J 58
 Woodhouse J M 95
 Woolley D G 149
 Wooten B R 189
 Wright O A 194
 Wu C Q 31
 Wuergler S M 201
 Wurtz R H 10
 Xiao D 120
 Xiao J 21
 Xiao X 61
 Xiao Y 21, 59
 Xiong D 90
 Yagi A 37
 Yagi Y 154
 Yakimova E G 13, 103
 Yakovlev V 123, 124
 Yakushev A G 86, 223
 Yamada H 207
 Yamada Y 202
 Yamaguchi M K 4a, 4b, 37, 92, 93
 Yamashita Y 191
 Yamazato K 139
 Yang Q 88
 Yarrow K 85
 Yates T A 227
 Yeh S-L 78, 80, 159
 Ygge J 94
 Yoshino D 77
 Yoshizawa T 36, 152
 Zaccardi G 142
 Zaenen P 39
 Zaidi Q 182
 Zanetti G 37
 Zanforlin M 183
 Zanker J M 218, 220, 237
 Zatorre R 14
 Zavagno D 182, 228
 Zaychik A 94
 Zdravković S 181
 Zeil J 165
 Zetsche C 62
 Zhang H 26
 Zhang Q 183
 Zhaoping L 71, 163, 233b, 233c
 Zhou B 63
 Zhou J 61
 Zhuravsky 95
 Zlatkova M B 193
 Zoccolotti P 174
 Zohary E 124
 Zueva M V 232
 Zwan R van der 144